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Vertical Drop Test of a Beechcraft 1900C Airliner

Robert McGuire and Dr. Tong Vu

Federal Aviation Administration
Airworthiness Assurance R&D Branch
William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

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Final Report

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16. Abstract

A commuter category Beechcraft 1900C airliner was subjected to a vertical impact drop test at the FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey. The purpose of this test was to measure the impact response of the fuselage, cabin floor, cabin furnishings (including standard and modified seats), and anthropomorphic test dummies. The test was conducted to simulate the vertical velocity component of a severe but survivable crash impact. A low-wing, 19-passenger fuselage was dropped from a height of 11′ 2″ resulting in a vertical impact velocity of 26.8 ft/sec. The airframe was configured to simulate a typical flight condition, including seats (normal and experimental), simulated occupants, and cargo. For the test the wings were removed; the vertical and horizontal stabilizers were removed; the landing gear was removed; and the pilot and copilot seats were not installed. The data collected in the test and future tests will supplement the existing basis for improved seat and restraint systems for commuter category 14 Code of Federal Regulation (CFR) Part 23 airplanes.

The test article was fully instrumented with accelerometers and load cells. Seventy-nine data channels were recorded. Results of the test are as follows:

- the fuselage experienced an impact in the range of 140-160 g's, with an impact pulse duration of 9-10 milliseconds
- the simulated occupants experienced g levels in the range of 32-45 g's with a pulse duration of 44-61 milliseconds
- the test was considered to be a severe but definitely survivable impact
- the fuselage structure maintained a habitable environment during and after the impact
- the seat tracks remained attached to the fuselage along the entire length of the fuselage
- all standard seats remained in their tracks after the impact
- all exits remained operable
- all the test dummies experienced lumbar loads in excess of the current maximum requirement found in 14 CFR 23.562(c)(2)

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- all the test dummies experienced lumbar loads in excess of the current maximum requirement found in 14 CFR 23.562(c)(2)

INTRODUCTION

This report presents the results of a dynamic airplane vertical impact test conducted at the William J. Hughes Technical Center, Atlantic City International Airport, New Jersey. The purpose of the test was to determine the impact response of the fuselage, cabin floor, cabin furnishings (including standard and modified seats), and anthropomorphic test dummies. The test was conducted to simulate the vertical velocity component of a severe but survivable crash impact. A low-wing Beechcraft 1900C 19-passenger commuter airliner fuselage was dropped from a height of 11′ 2″ resulting in a vertical impact velocity of 26.8 ft/sec. The airframe was configured to simulate a typical flight condition, including seats, simulated occupants, and cargo. The data collected in the test and future tests will supplement the existing basis for improved seat and restraint systems for commuter category 14 Code of Federal Regulation (CFR) Part 23 airplanes.

BACKGROUND

This vertical impact test is one of a series of fuselage section and full-scale airplane tests conducted in support of the Federal Aviation Administration's (FAA) ongoing Aircraft Safety Research Plan [1]. The FAA has proposed seat dynamic performance standards for 14 CFR Part 23 commuter category airplanes. Those standards were established empirically using the results of prior airplane crash impact test programs. In development of those standards, it was noted that the full-scale airplane impact test database did not include airplanes representative in size of the commuter category airplanes. To provide data for those size airplanes, the FAA initiated a full-scale vertical impact test program of 14 CFR Part 23 commuter category airplanes. A test of a Metro III aircraft was conducted in April 1992 [2]. The tests were structured to assess the impact response characteristics of airframe structures, seats, and the potential for occupant impact injury.

DESCRIPTION OF TEST FACILITY AND TEST ARTICLE

TEST FACILITY.

The Technical Center drop test facility, shown in figure 1, is comprised of two 50-foot vertical steel towers connected at the tops by a horizontal platform. An electrically powered winch, mounted on the horizontal platform, is used to raise or lower the test article and is controlled from the base of one of the tower legs. The current lifting capacity of the winch is 13,600 pounds. Attached to the winch is a reeved hoisting cable which is used to raise the test article. A sheave block assembly hanging from the free end of the reeved cable is engaged to a solenoid operated release hook. The release hook is connected to the airframe by a cable/turnbuckle assembly with hooks bolted to the fuselage section at four locations. Located below the winch cable assembly and between the tower legs is a 15- by 36-foot wooden platform which rests upon I-beams and is supported by 12 independent load cells.

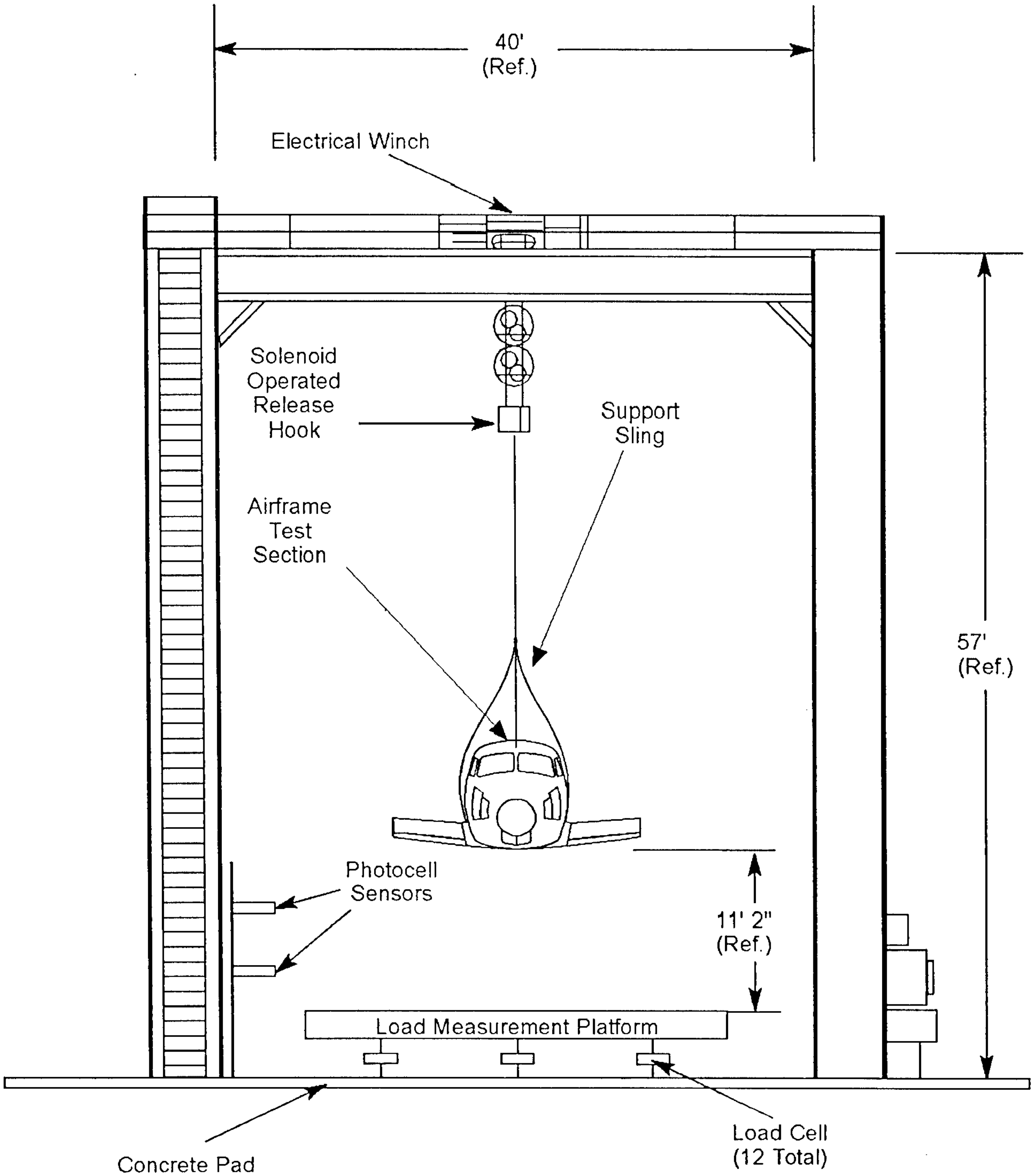


FIGURE 1. DROP TEST FACILITY

TEST ARTICLE.

The test article was a Beechcraft 1900C which is a low-wing, twin-turboprop, 19-passenger commuter airliner 57′ 10″ in length. The following modifications were made to the airplane prior to the test:

- The wings and engines were removed from the fuselage wing box structure.
- The vertical and horizontal stabilizers were removed from the empennage; however, ballast was added to the tail section of the airplane to compensate for the missing stabilizers.
- The landing gear was removed.
- The pilot and copilot seats were not installed; ballast was added to simulate the weight of the seats and occupants.

The internal seating arrangement was modified for the test to accommodate a variety of seats. Seats included in this test were PTC Aerospace seats, Wichita State University (WSU) experimental energy-absorbing seats, the FAA Civil Aeromedical Institute's (CAMI) experimental energy-absorbing seat, a center aisle Beechcraft seat, and standard Beechcraft seats both blue and brown in color. The blue and brown Beechcraft seats are structurally identical except the brown seats have a lower seat back. The following is a listing of the type of seats located at the fuselage stations (FS) along the length of the airplane. Seat configuration and locations are shown in figure 2:

FS 129 - Flight deck seats were not installed, ballast was used
FS 200 - Wichita State University experimental energy-absorbing seat
FS 230 - Standard Beechcraft seat (blue)
FS 260 - WSU experimental seat and standard Beechcraft seat (blue)
FS 290 - Standard Beechcraft seat (blue) and PTC Aerospace seat
FS 320 - FAA Civil Aeromedical Institute's energy-absorbing seat
FS 350 - Center aisle Beechcraft seat
FS 380 - PTC Aerospace seat and standard Beechcraft seat (blue)
FS 410 - Two standard Beechcraft seats (blue)
FS 440 - Two standard Beechcraft seats (brown)

Each of the seats was occupied by a test dummy or ballast to represent the weight of a 170-pound occupant. Seven of the seats were occupied by instrumented Hybrid II anthropomorphic test dummies (ATD), six others were occupied by dummies without instrumentation capability, and one seat was loaded with a wooden body block. Figure 2 shows the locations of the ATDs. All the dummies and ballast were strapped firmly into the seats with lap belt restraint systems.

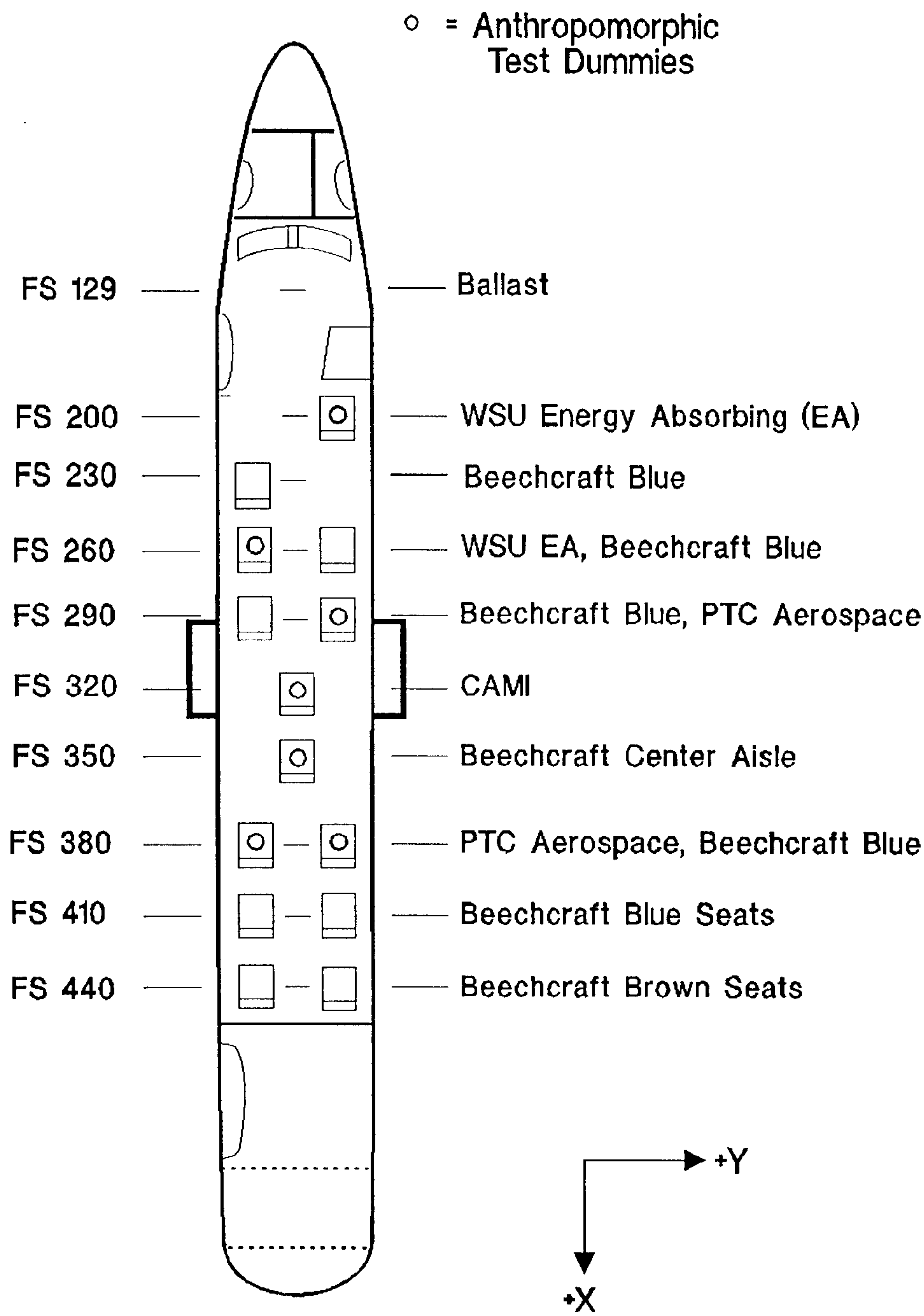


FIGURE 2. BEECHCRAFT 1900C AIRLINER

The total weight of the test article was 8475 pounds. This weight represents the maximum gross takeoff weight of the airplane, taking into consideration the weight of the portions of the airplane that were removed. A list of all individual item weights and moments about the aircraft datum are presented in table 1.

The test article also had seven onboard cameras which will be discussed in the instrumentation section of this report.

TABLE 1. TEST ARTICLE WEIGHT

	Item	Fuselage Station	Weight Lb.	Moment
FUSELAGE	Fuselage	303	2205	668115
	Plates	135	400	54000
	Seat/ATD	200	193	38600
	Seat/Dummy	230	180	41400
	Seats/ATD/Dummy	260	366	95160
	Seats/ATD/Dummy	290	343	99470
	Seat/ATD	320	245	78400
	Seat/ATD	350	240	84000
	Seats/ATDs	380	366	139080
	Seats/Dummies	410	360	147600
	Seats/Dummies	440	353	155320
BALLAST	Shot	55	26	1430
	Baggage	71	326	23146
	Plates	120	135	16200
	Plates	130	200	26000
	Shot	164	52	8528
	Plates	170	500	85000
	Shot	190	104	19760
	Shot	211	78	16458
	Shot	220	52	11440
	Shot	311	52	16172
	Shot	341	104	35464
	Shot	356	26	9256
	Shot	371	52	19292
	Shot	386	52	20072
	Shot	431	52	22412
	Baggage	482	464	223648
	Baggage	485	300	145500
	Plates	544	325	176800
CAMERA	Miscellaneous	303	122	36966
	Camera/Mount	138	54	7452
	Camera/Mount	150	40	6000
	Camera/Mount	203	13	2639
	Camera/Mount	234	38	8892
	Camera/Mount	370	13	4810
	Camera/Mount	518	31	16058
	Camera/Mount	567	13	7371
		TOTAL	8475	2567911
		CENTER OF GRAVITY	FS 303	

TEST INITIATION

Prior to the test, the airframe test section was leveled by adjusting the supporting turnbuckles. The test article was then raised to the desired height of 11′ 2″. Four guide ropes, manned by members of the drop test team, steadied the test article while it hung above the platform. Once the test article was steady and level, the timing sequence began, the high-speed film cameras began running, and the airplane was released and began accelerating toward the platform. At the point of impact with the platform the fuselage section had reached a velocity of 26.8 ft/sec. Wind speed during the test was less than 5 mph.

INSTRUMENTATION

FUSELAGE.

The fuselage instrumentation for this test included 39 accelerometers located at various stations along the length of the airplane. Thirty-four of the accelerometers were rated for 750 g's, four were rated for 100 g's, and one was rated for 200 g's. The accelerometers were located on the floor, the side wall seat track, and along the side wall to determine the fuselage response throughout its entire length. A complete listing of all the accelerometer locations is given in table 2.

SEATS.

The two WSU energy-absorbing seats were instrumented with accelerometers to determine their impact response directly. The WSU seats were located at FS 200 and FS 260, and each had one accelerometer attached to its seat pan.

TEST DUMMIES.

Seven of the test dummies were 50th percentile Hybrid II anthropomorphic dummies. All of the anthropomorphic test dummies were instrumented with load cells and accelerometers. The instrumented test dummies were located at fuselage stations 200, 260, 290, 320, 350, and 380 (see figure 2).

PLATFORM LOAD CELLS.

The impact platform rests on 12 load cells, each with a load capacity of 50,000 pounds. A hydraulic jack is located under each load cell, and each jack was activated simultaneously with a central pump. After the platform was raised off the ground, its tare weight was zeroed by the computer system. The platform load cells measured the reactive forces generated during the drop of the test article and were used to verify the impact loads and determine their distribution.

CAMERAS.

Five high-speed film cameras were used to record the exterior of the airplane during the test. One forward view, two quarter views, and one side view of the test article were filmed. The fifth camera, intended to provide a rear view of the test article, malfunctioned during the test.

TABLE 2. INSTRUMENTATION

Instrumentation	ID Number	Direction/ Load	Location X	Y	Z	Description
Accelerometer	AA72	-Z	129	9	0	Floor Seat Track
Accelerometer	AA49	Z	129	-9	0	Floor Seat Track
Accelerometer	AA67	-Z	129	27	24	Side Wall
Accelerometer	A93G	-Z	129	-27	24	Side Wall
Accelerometer	CV29	Z	200	9	0	Floor Seat Track
Accelerometer	CV70	-Z	200	27	11	Side Seat Track
Accelerometer	A71F	Y	200	27	11	Side Seat Track
Accelerometer	A90D	Z	200	20	20	Seat Pan
Accelerometer	DE93	Z	200	-9	0	Floor Track
Accelerometer	A78F	Z	200	-27	11	Side Track
Accelerometer	AA57	Z	200	27	24	Side Wall
Accelerometer	AA24	Z	200	-27	24	Side Wall
Accel (100 G)	AG3A3	-Z	200	-27	24	Side Wall
Accelerometer	A77F	Z	260	9	0	Floor Seat Track
Accelerometer	A67F	Z	260	27	11	Side Seat Track
Accelerometer	A70F	-Z	260	20	20	Seat Pan
Accelerometer	AA86	Z	260	-9	0	Floor Seat Track
Accelerometer	A90F	Z	260	-27	11	Side Seat Track
Accelerometer	GK19	Y	260	-27	11	Side Seat Track
Accelerometer	A53F	Z	260	-20	20	Seat Pan
Accelerometer	DA11	Z	260	27	24	Side Wall
Accelerometer	A77J	Z	260	-27	24	Side Wall
Accel (100 G)	AG3A1	-Z	260	27	24	Side Wall
Accel (200 G)	AJ13	-Z	260	27	24	Side Wall
Accelerometer	DE12	Z	290	9	0	Floor Seat Track
Accelerometer	AA96	Z	290	27	11	Side Seat Track
Accelerometer	CR31	Z	290	-9	0	Floor Seat Track
Accelerometer	AA74	Z	290	-27	11	Side Seat Track
Accelerometer	DB59	Z	320	9	0	Floor Seat Plate
Accelerometer	A52K	Z	320	-9	0	Side Seat Plate
Accelerometer	A53J	Z	320	27	24	Side Wall
Accelerometer	A79J	Z	320	-27	24	Side Wall
Accel (100 G)	ACKNO	-Z	320	-27	24	Side Wall
Accelerometer	A32F	Z	350	9	0	Floor Seat Plate
Accelerometer	AA98	Z	350	-9	0	Floor Seat Plate
Accelerometer	DE92	Z	410	9	0	Floor Seat Track
Accelerometer	CZ31	Z	410	27	11	Side Seat Track
Accelerometer	DB62	Z	410	-9	0	Floor Seat Track
Accelerometer	AO1D	Z	410	-27	11	Side Seat Track
Accelerometer	CJ46	Z	410	27	24	Side Wall
Accelerometer	AA89	Z	410	-27	24	Side Wall
Accel (100 G)	ACKT1	-Z	410	27	24	Side Wall
Load Cell	91174LC	LBS/mV	200	17	15	ATD, WSU EA Seat
Accel (100 G)	AEH88	-Z	200	17	15	ATD, WSU EA Seat
Accelerometer	AA59	-Z	200	17	15	ATD, WSU EA Seat

TABLE 2. INSTRUMENTATION (CONTINUED)

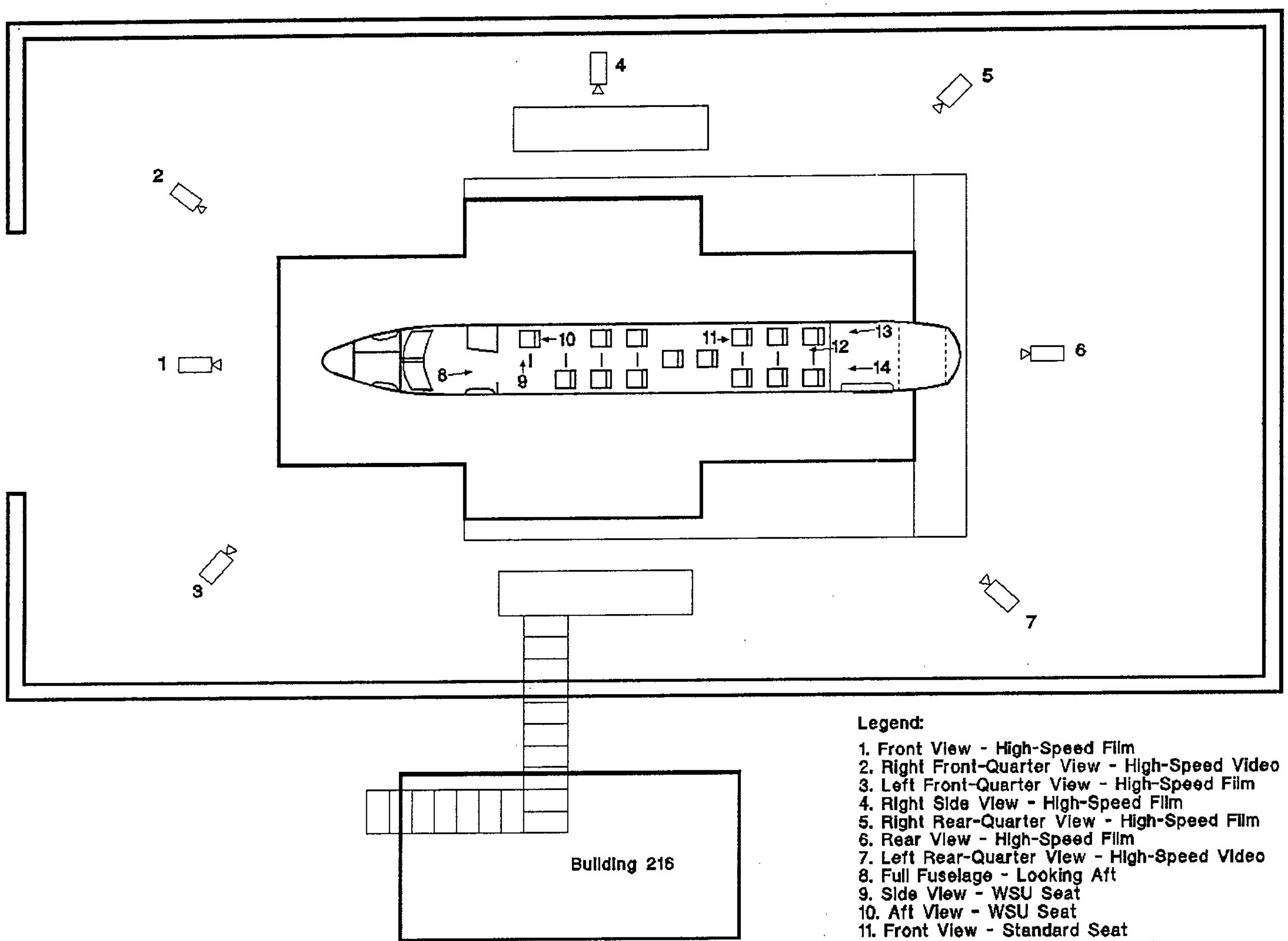
Instrumentation	ID Number	Direction/ Load	Location X	Y	Z	Description
Load Cell	91174LC	LBS/mV	260	-17	15	ATD, WSU EA Seat
Accelerometer	AG3D0	-Z	260	-17	15	ATD, WSU EA Seat
Accelerometer	AA58	-Z	260	-17	15	ATD, WSU EA Seat
Load Cell	91202LC	LBS/mV	290	17	15	ATD, PTC Seat
Accelerometer	CX08	-Z	290	17	15	ATD, PTC Seat
Accelerometer	AGGP1	-Z	290	17	15	ATD, PTC Seat
Load Cell	91175LC	LBS/mV	320	0	15	ATD, CAMI Seat
Accel (100 G)	AF0Y1	-Z	320	0	15	ATD, CAMI Seat
Accelerometer	AA73	-Z	320	0	15	ATD, CAMI Seat
Load Cell	91201LC	LBS/mV	350	0	15	ATD, Beech Center Seat
Accel (100 G)	AF1C0	-Z	350	0	15	ATD, Beech Center Seat
Accelerometer	DA74	-Z	350	0	15	ATD, Beech Center Seat
Load Cell	91211LC	LBS/mV	380	17	15	ATD, Regular Seat
Accel (100 G)	AG3D2	-Z	380	17	15	ATD, Regular Seat
Accelerometer	A95G	-Z	380	17	15	ATD, Regular Seat
Accel (100 G)	ACKR6	-Z	380	-17	15	ATD, PTC Seat
Accelerometer	AA77	-Z	380	-17	15	ATD, PTC Seat
Load Cell	99059LC	LBS/mV	380	-17	15	ATD, PTC Seat
Load Cell	213542	LBS/mV				Platform 1st Row, Left
Load Cell	372136	LBS/mV				Platform 1st Row, Center
Load Cell	213540	LBS/mV				Platform 1st Row, Right
Load Cell	113934	LBS/mV				Platform 2nd Row, Left
Load Cell	213534	LBS/mV				Platform 2nd Row, Center
Load Cell	213541	LBS/mV				Platform 2nd Row, Right
Load Cell	213536	LBS/mV				Platform 3rd Row, Left
Load Cell	213538	LBS/mV				Platform 3rd Row, Center
Load Cell	213537	LBS/mV				Platform 3rd Row, Right
Load Cell	213543	LBS/mV				Platform 4th Row, Left
Load Cell	113936	LBS/mV				Platform 4th Row, Center
Load Cell	113939	LBS/mV				Platform 4th Row, Right

Note: All accelerometers were manufactured by Endevco Inc.
All platform load cells were manufactured by Sensotec Inc.
All anthropomorphic test dummy load cells were manufactured by Denton Inc.
All instrumentation excitation voltage was 10 volts.

In addition to the high-speed film, two high-speed video cameras were placed outside the fuselage to record front- and rear-quarter views.

Seven high-speed film cameras were located in the test article. These cameras focused on various seats in addition to providing an overall view of the activity inside the fuselage during the test. However, due to a malfunction of the test sequencer, the flash bulbs ignited a few milliseconds too late. The lack of proper lighting inside the airplane rendered the film virtually useless due to under exposure.

Figure 3 shows the location of both the onboard and external cameras.



Legend:

1. Front View - High-Speed Film
2. Right Front-Quarter View - High-Speed Video
3. Left Front-Quarter View - High-Speed Film
4. Right Side View - High-Speed Film
5. Right Rear-Quarter View - High-Speed Film
6. Rear View - High-Speed Film
7. Left Rear-Quarter View - High-Speed Video
8. Full Fuselage - Looking Aft
9. Side View - WSU Seat
10. Aft View - WSU Seat
11. Front View - Standard Seat
12. Floor Track - Looking Forward
13. Full Fuselage - Looking Forward
14. Rear Seats - Looking Forward

FIGURE 3. CAMERA LOCATIONS

DATA ACQUISITION

DATA ACQUISITION SYSTEM.

The NEFF 490 data acquisition system is a high-speed data acquisition system which has the capability to sample and record data at sampling rates up to 1 MHz. The system consists of 92 channels. Each channel includes a 12 bit analog-to-digital converter with an accuracy of 0.1% of programmable full scale, a 6-pole Bessel low-pass filter with four programmable cutoff frequencies which cover a range from 100 Hz to 200 kHz, and a differential input amplifier with 12 programmable gain steps. Input signals range from ±5 mV dc to ±10.24 V dc full scale.

For the test, the system was set to sample and record 79 channels of data simultaneously at 10,000 samples per second per channel. All data channels were prefiltered at a cutoff frequency of 1 kHz and temporarily stored in the NEFF 256K word DRAM memory during the test. Test data were then transferred to an IBM compatible computer by an IEEE-488 interface for further analysis. The full-scale value for a channel was chosen based on an estimate of the maximum output of the sensor on the channel. Full-scale values for each sensor as well as engineering unit conversion and measured sensitivity are shown in table 3.

TABLE 3. DATA ACQUISITION SYSTEM CONFIGURATION AND CALIBRATION

CHANNEL NUMBER	FULL-SCALE VALUE (mV)	ENGINEERING UNIT CONVERSION	BALANCE OUTPUT (mV)	MEASURED SENSITIVITY
101	20	G's = -0.26 + 5.63 x mV	0.000	0.1978 mV/G
102	40	G's = 0.011 + 5.43 x mV	0.000	0.2009 mV/G
103	40	G's = 0.011 + 5.39 x mV	0.000	0.2056 mV/G
104	5	Lbs = 3.21 + 597.47 x mV	0.002	0.0017 mV/lb
105	320	G's = 0.267773 x mV	0.000	3.8901 mV/G
106	20	G's = -0.202 + 4.804 x mV	0.000	0.2167 mV/G
107	40	G's = -0.349 + 5.259 x mV	0.000	0.2037 mV/G
108	-	Not Used	-	-
109	40	G's = -0.147 + 5.392 x mV	0.000	0.2008 mV/G
110	640	G's = 0.042 + 0.223 x mV	0.000	4.6637 mV/G
111	40	G's = -0.260 + 5.323 x mV	0.000	0.2019 mV/G
112	40	G's = -0.268 + 4.432 x mV	0.000	0.2392 mV/G
113	40	G's = -0.212 + 5.179 x mV	0.000	0.2137 mV/G
114	640	G's = -0.068 + 0.438 x mV	0.000	2.5020 mV/G
115	640	G's = 0.230172 x mV	0.000	4.8080 mV/G
201	40	G's = -0.108 + 5.03 x mV	0.000	0.2178 mV/G
202	40	G's = 0.163 + 5.227 x mV	0.000	0.2110 mV/G
203	40	G's = -0.077 + 5.602 x mV	0.000	0.1976 mV/G
204	5	Lbs = -0.29 + 592.88 x mV	0.000	0.0017 mV/lb
205	320	G's = 0.022 + 0.234 x mV	0.000	4.4090 mV/G
206	20	G's = -0.249 + 5.544 x mV	0.020	0.1860 mV/G
207	40	G's = -0.599 + 4.871 x mV	0.000	0.2277 mV/G

TABLE 3. DATA ACQUISITION SYSTEM CONFIGURATION AND CALIBRATION (CONTINUED)

CHANNEL NUMBER	FULL-SCALE VALUE (mV)	ENGINEERING UNIT CONVERSION	BALANCE OUTPUT (mV)	MEASURED SENSITIVITY
208	40	G's = -0.119 + 5.549 x mV	0.000	0.1975 mV/G
209	40	G's = -0.268 + 5.089 x mV	0.000	0.2157 mV/G
210	640	G's = 0.022 + 0.236 x mV	0.000	4.6143 mV/G
211	40	G's = -0.115 + 4.887 x mV	0.000	0.2141 mV/G
212	40	G's = -0.099 + 5.64 x mV	0.000	0.1932 mV/G
213	40	G's = -0.335 + 5.19 x mV	0.000	0.2010 mV/G
214	640	G's = 0.059 + 0.21 x mV	0.000	4.9933 mV/G
215	-	Not Connected	-	-
216	20	Lbs = 6.43 + 1645.24 x mV	0.000	0.0006 mV/lb
217	20	Lbs = 17.47 + 1626.53 x mV	0.000	0.0006 mV/lb
218	20	Lbs = 5.18 + 1767.33 x mV	0.000	0.0006 mV/lb
219	20	Lbs = -9.76 + 1666.31 x mV	0.000	0.0006 mV/lb
220	20	Lbs = 15.34 + 1570.76 x mV	0.010	0.0006 mV/lb
221	20	Lbs = 15.33 + 1744.64 x mV	0.010	0.0006 mV/lb
222	-	Not Used	-	-
223	-	Not Used	-	-
224	-	Not Used	-	-
225	20	Lbs = 1.86 + 1907.78 x mV	0.010	0.0005 mV/lb
226	20	Lbs = 4.90 + 1671.11 x mV	0.000	0.0006 mV/lb
227	20	Lbs = 12.6 + 1612.91 x mV	0.010	0.0006 mV/lb
228	20	Lbs = 6.60 + 1690.56 x mV	0.000	0.0006 mV/lb
229	20	Lbs = 3.46 + 1769.72 x mV	0.000	0.0006 mV/lb
230	20	Lbs = 16.04 + 1824.84 x mV	0.020	0.0005 mV/lb
301	40	G's = 0.05 + 5.138 x mV	0.098	0.2031 mV/G
302	40	G's = -0.376 + 5.25 x mV	0.000	0.2071 mV/G
303	40	G's = -0.194 + 5.219 x mV	0.000	0.2076 mV/G
304	640	G's = -0.023 + 0.182 x mV	0.000	5.9541 mV/G
305	40	G's = -0.076 + 5.565 x mV	0.000	0.1987 mV/G
306	40	G's = -26.28 + 7.257 x mV	0.000	0.1890 mV/G
307	40	G's = -0.571 + 5.516 x mV	0.000	0.2021 mV/G
308	40	G's = -0.268 + 5.489 x mV	0.000	0.1977 mV/G
309	40	G's = -0.522 + 5.57 x mV	0.000	0.2042 mV/G
310	5	Lbs = -4.38 + 598.17 x mV	0.002	0.0017 mV/lb
311	320	G's = -0.01 + 0.219 x mV	0.000	4.7514 mV/G
312	20	G's = -0.138 + 4.70 x mV	0.000	0.2203 mV/G
313	160	MPH = 0.1594 x mV	-	-
314	-	Not Used	-	-
315	-	Not Used	-	-
401	40	G's = -0.492 + 5.359 x mV	0.000	0.2021 mV/G
402	40	G's = -0.155 + 4.974 x mV	0.000	0.2217 mV/G
403	40	G's = -0.562 + 5.231 x mV	0.000	0.2072 mV/G
404	20	G's = -0.408 + 6.325 x mV	0.000	0.1632 mV/G

TABLE 3. DATA ACQUISITION SYSTEM CONFIGURATION AND CALIBRATION (CONTINUED)

CHANNEL NUMBER	FULL-SCALE VALUE (mV)	ENGINEERING UNIT CONVERSION	BALANCE OUTPUT (mV)	MEASURED SENSITIVITY
405	320	G's = 0.206247 x mV	0.000	5.0210 mV/G
406	5	Lbs = 8.509 + 590.74 x mV	0.002	0.0017 mV/lb
407	40	G's = -0.175 + 5.26 x mV	0.000	0.2090 mV/G
408	40	G's = 0.086 + 5.522 x mV	0.000	0.2009 mV/G
409	40	G's = -0.193 + 5.482 x mV	0.000	0.1982 mV/G
410	40	G's = -0.27 + 5.524 x mV	0.000	0.1999 mV/G
411	40	G's = -0.941 + 5.477 x mV	0.000	-0.2032 mV/G
412	40	G's = -0.254 + 5.411 x mV	0.000	0.2029 mV/G
413	40	G's = -0.467 + 5.56 x mV	0.000	0.1956 mV/G
414	40	G's = -0.278 + 6.46 x mV	0.000	0.1692 mV/G
415	40	G's = -0.363 + 5.81 x mV	0.000	0.1894 mV/G
416	5	Lbs = 3.97 + 602.35 x mV	0.000	0.0017 mV/lb
417	320	G's = 0.03 + 0.21 x mV	0.000	4.8762 mV/G
418	20	G's = -0.403 + 4.538 x mV	0.000	0.2260 mV/G
419	5	Lbs = 4.575 + 567.88 x mV	0.007	0.0018 mV/lb
420	320	G's = 0.106 + 0.261 x mV	0.000	3.9992 mV/G
421	20	G's = -0.217 + 5.417 x mV	0.000	0.1896 mV/G
422	5	Lbs = 4.361 + 595.46 x mV	0.000	0.0017 mV/lb
423	320	G's = 0.007 + 0.233 x mV	0.000	4.4746 mV/G
424	20	G's = -0.57 + 5.402 x mV	0.000	0.1921 mV/G
425	40	G's = -0.072 + 5.302 x mV	0.000	0.1915 mV/G
426	-	Not Used	-	-
427	-	Not Used	-	-
428	10240	Velocity Trap	-	-

Before the test, the bridge output voltage of each channel's sensor was balanced to zero to compensate for any variation in the zero state of the sensor. The channels were then calibrated. All phases of balancing the bridge output voltage, calibrating the channels, measuring sensitivity, and determining conversion coefficients for calculating engineering units were controlled by the data acquisition system software based upon operator inputs. The pretest data are shown in table 3.

The system was externally triggered by the sequencer unit which controlled all the test processes. Block recording mode was selected for the NEFF 490 system to prevent any time shifts that might have occurred due to the use of two control computers.

WORK STATION.

Two IBM compatible NCR 3230 systems with 486 microprocessor chips having a clock speed of 33 MHz were configured to run the NEFF 490 system software and to download data from the NEFF 490 DRAM memory. DADiSP software was then used to import the NEFF data for further analysis.

DATA ANALYSIS

DATA REDUCTION.

As stated, the sensor data was first filtered with a 1 kHz analog filter and then recorded at a sampling rate of 10,000 samples/second. The data were then filtered with a SAE J211 class 600 digital filter for the anthropomorphic dummy load cell data channels and class 60 digital filter for the acceleration and platform load cell data channels.

The data were recorded for 22 seconds starting 3 seconds prior to hook release. However, only 100 milliseconds of data, starting 10 milliseconds before the impact, are presented in this report.

TIME TO IMPACT.

The test data showed that the test article impacted at 845 milliseconds after hook release. This is close to the expected free-fall time (t = 0.834 sec) which is calculated by the equation

$$t = \sqrt{2h / g} \tag{1}$$

where h is the drop test distance (11′ 2″), and g is the acceleration due to gravity (32.2 ft/sec^2). After impact, the test article rebounded off the platform surface. From the film analysis it was determined that the rebound occurred approximately 60 milliseconds after impact.

TEST VELOCITY.

The impact velocity was verified by comparing the analytical velocity to the measured velocity and the observed velocity. Using the energy conservation principal, the analytical impact velocity (v_f) can be determined by the equation

$$v_f = \sqrt{2gh} \tag{2}$$

where h is the drop test distance (11′ 2″), and g is the acceleration due to gravity (32.2 ft/sec^2).

By observing the films of the front-view, quarter-view, and side-view cameras which were equipped with IRIG B timing devices, the free-fall time was determined to be approximately 829 milliseconds. The impact velocity was then calculated using the kinematic linear motion equation

$$v_f - v_o = gt \tag{3}$$

where g is the acceleration due to gravity (32.2 ft/sec^2) and v_o is the initial velocity (v_o = 0 ft/s).

According to the data recorded by the velocity trap, see figure 4, the time it took for the test article to travel through the two optical sensors was 38.2 milliseconds. Therefore, the measured

velocity can be determined by the following equation:

$$v_f = \frac{\Delta d}{\Delta t} \tag{4}$$

where $\Delta d = 1$ ft.

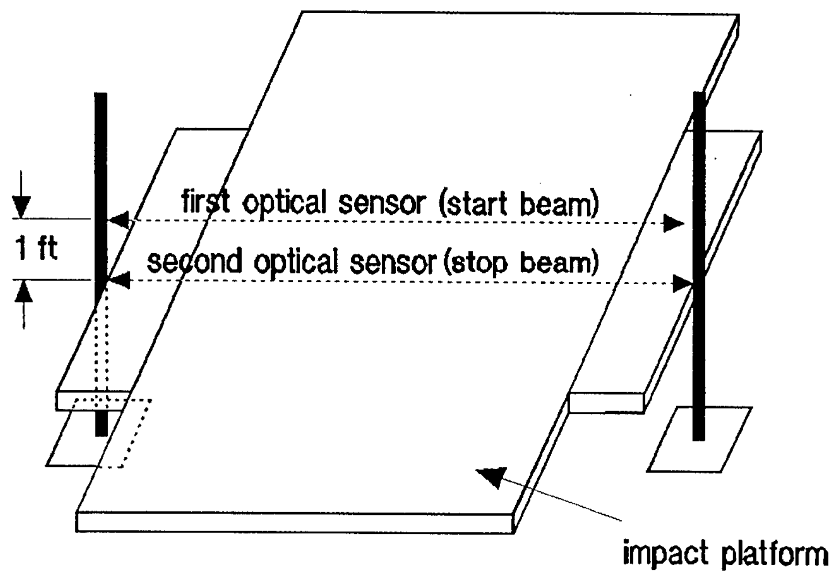


FIGURE 4. VELOCITY SYSTEM SETUP

Table 4 shows the drop test velocity obtained using the different methodologies.

TABLE 4. DROP TEST VELOCITY

Methodology	Velocity (ft/sec)
Analytical	26.8
Film Observation	26.7
Measurement	26.2

FUSELAGE STRUCTURE.

PERMANENT DEFORMATION. Due to the structure of the fuselage and the uneven platform surface, the posttest fuselage deformations varied from station to station. At the bottom of the test article, there was little or no crush at the wing box section and the pilot/copilot section. However, deformation of the fuselage from FS 188 through FS 243 and from FS 333 through FS 423 was noted. The measurements of the bottom deformation at FS 200, FS 260, FS 320, and FS 410 were 1.2, 0.3, 0.5, and 1.6 inches respectively.

AIRFRAME ACCELERATION. Most of the airframe acceleration raw data exceeded the full-scale limit of the data acquisition system which was set at ±200 g's. However, if the data remained within the linear range of the accelerometer, which was the case for all 750 g accelerometers, the data were used in the analysis. If the data experienced minor clipping or no clipping, it was deemed reliable for determining the impact pulse and the results are reported. Any data that significantly exceeded the ±200 g range was not considered valid for analysis. To compensate for the platform response (which was superimposed on the airframe response), the data were corrected by subtracting the platform acceleration data from the airframe acceleration data. These filtered and corrected data are plotted in appendix A, while typical raw data channels are plotted in appendix B.

The airframe accelerations are presented in three separate groups: the floor track accelerations, the side wall seat track accelerations, and the fuselage side wall accelerations. The G_{peak} values were read directly from the filtered data. G_{max} normalized values were computed using equation 5 which assumes an idealized triangular pulse

$$G_{max} = \frac{2\Delta V}{\Delta t} \tag{5}$$

where Δt is the difference between the start and stop times of the integration interval, and ΔV is the velocity change determined by integrating the acceleration data during Δt.

The data in appendix A indicate that the test article experienced a secondary pulse at some fuselage stations during impact. To determine the g level of the impact, only the primary pulse should be used. The secondary pulse is inconsequential and, in fact, would cause an erroneous calculation of G_{max}. To compensate for the secondary pulse in the G_{max} calculation, the total velocity change was computed by adding two different velocity changes. In figure 5, a simplified presentation is made of a primary and secondary pulse. To compensate for the secondary pulse in the G_{max} calculation, the total velocity change was computed by adding from time t_1 to time t_2 to cover areas A and B but not C.

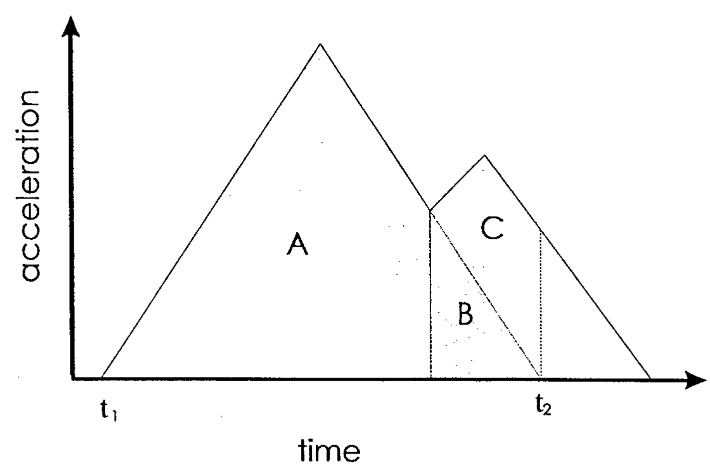


FIGURE 5. TYPICAL PRIMARY AND SECONDARY IMPACT PULSE

All the floor seat track acceleration raw data and some of the side wall seat track and side wall acceleration raw data exceeded the full-scale setting of the data acquisition system which was set at ±200 g's. However, as noted above, as long as the data remained in the linear range of the accelerometer (which was the case for all the 750 g accelerometers) and if only minor clipping was experienced, the data were considered reliable and used for the analysis.

Posttest inspection of the fuselage showed that the sensor at FS 200 mounted on the left floor seat track was dislodged during the impact, and a small piece of the right floor seat track near the sensor was broken due to the collapse of the WSU/EA seat. Therefore the data recorded on this sensor were invalid.

The normalized acceleration data of the floor seat track, the side wall seat track, and the side wall as well as the impact pulse duration's are presented in figures 6, 7, and 8 respectively. Tables 5, 6, and 7 show G_{peak} values, G_{max} values, and time duration of G_{max} pulse. The results of two lateral sensors at FS 200 right side and FS 260 left side are shown in appendix A, figures A-17 and A-18, respectively.

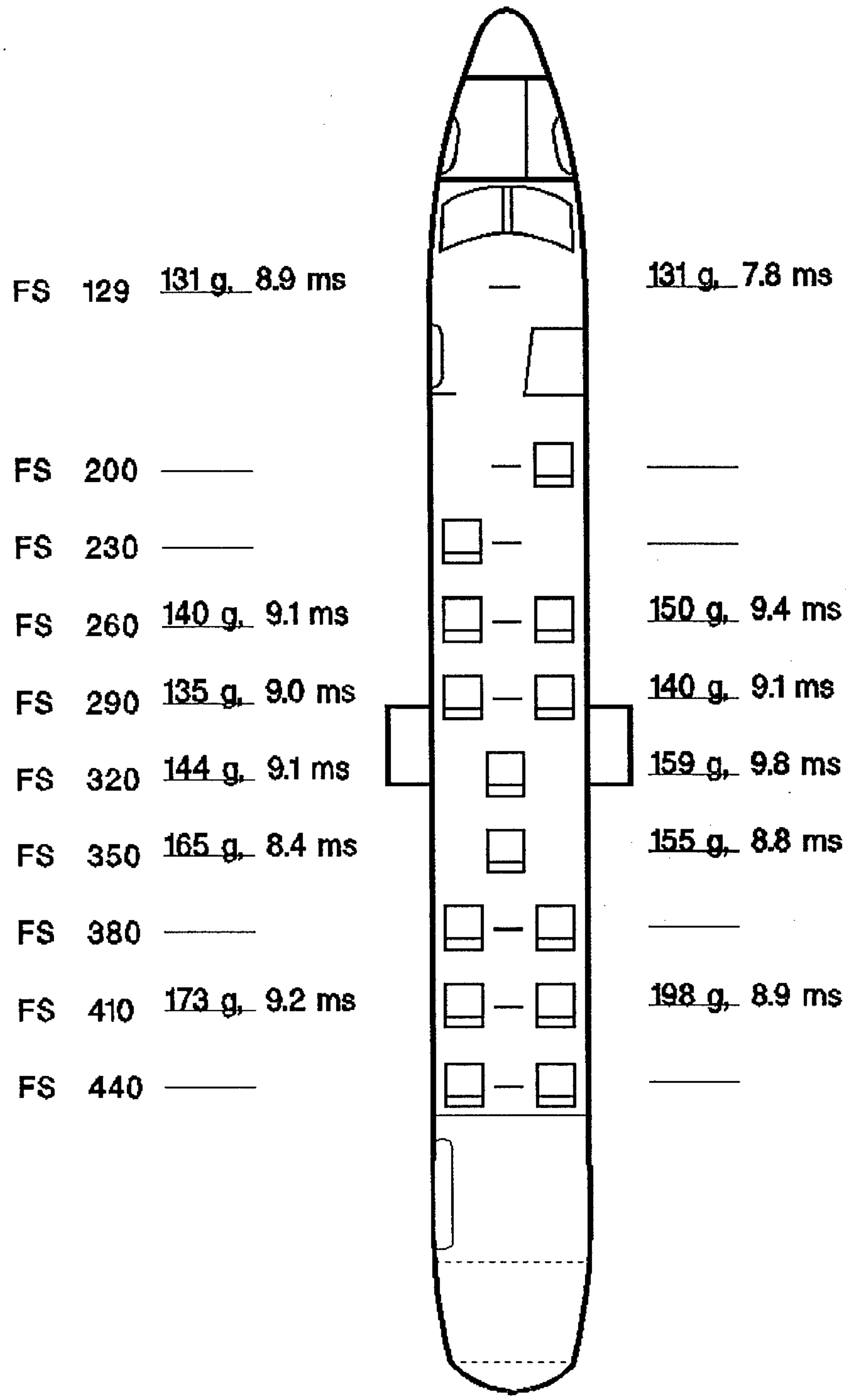


FIGURE 6. FLOOR SEAT TRACK ACCELERATIONS (G_{max})

TABLE 5. FLOOR SEAT TRACK ACCELERATIONS

Fuselage Station	G_{peak} (g)	G_{max} (g)	Pulse Duration (msec)
FS 129 P	135	131	8.9
FS 129 C	129	131	7.8
FS 200 P	Invalid	Invalid	Invalid
FS 200 C	Invalid	Invalid	Invalid
FS 260 P	148	140	9.1
FS 260 C	162	150	9.4
FS 290 P	143	135	9.0
FS 290 C	151	140	9.1
FS 320 P	153	144	9.1
FS 320 C	168	159	9.8
FS 350 P	168	165	8.4
FS 350 C	162	155	8.8
FS 410 P	170	173	9.2
FS 410 C	191	198	8.9

NOTE: P = Pilot/left side, C = Copilot/right side
Invalid data at FS 200 due to affect of WSU seat collapse

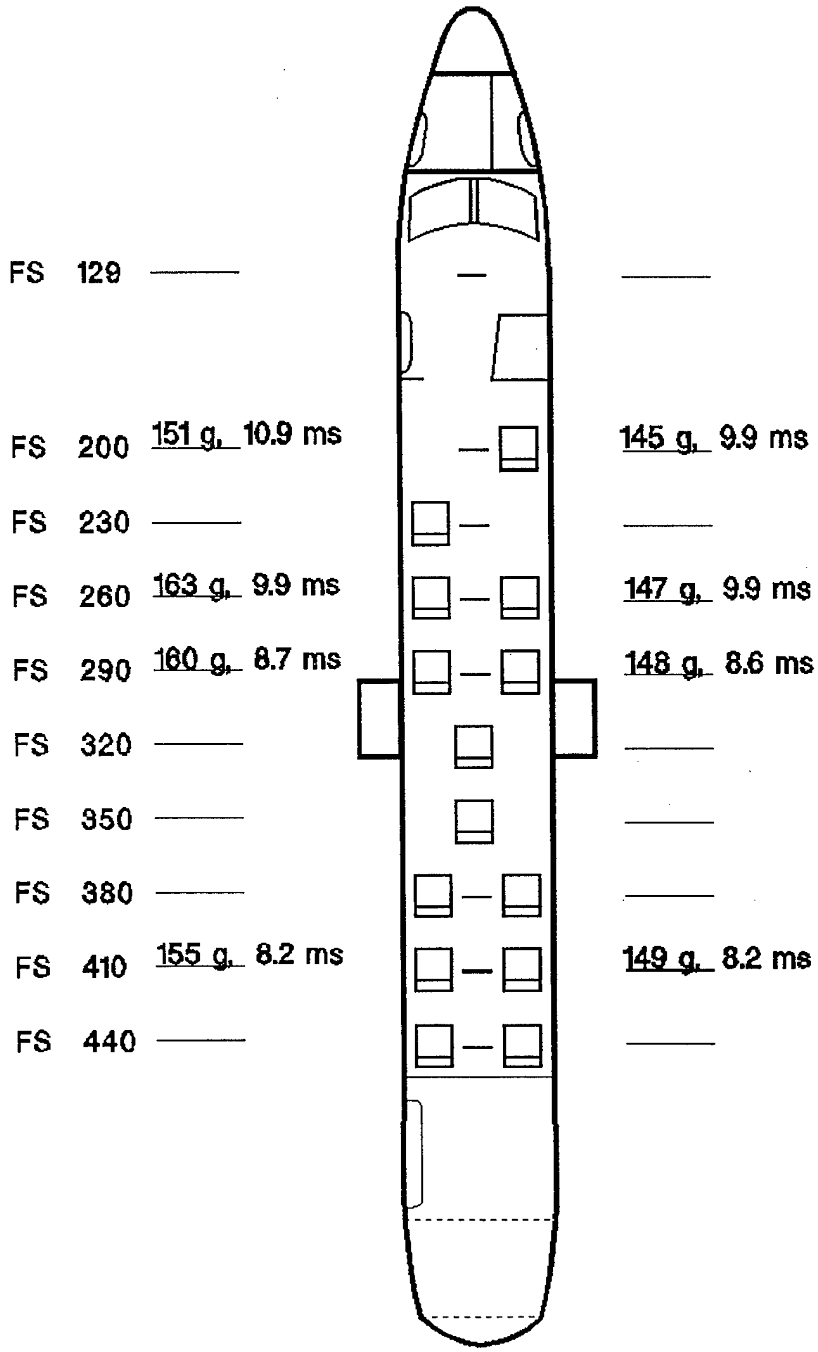


FIGURE 7. SIDE WALL SEAT TRACK ACCELERATIONS (G_{max})

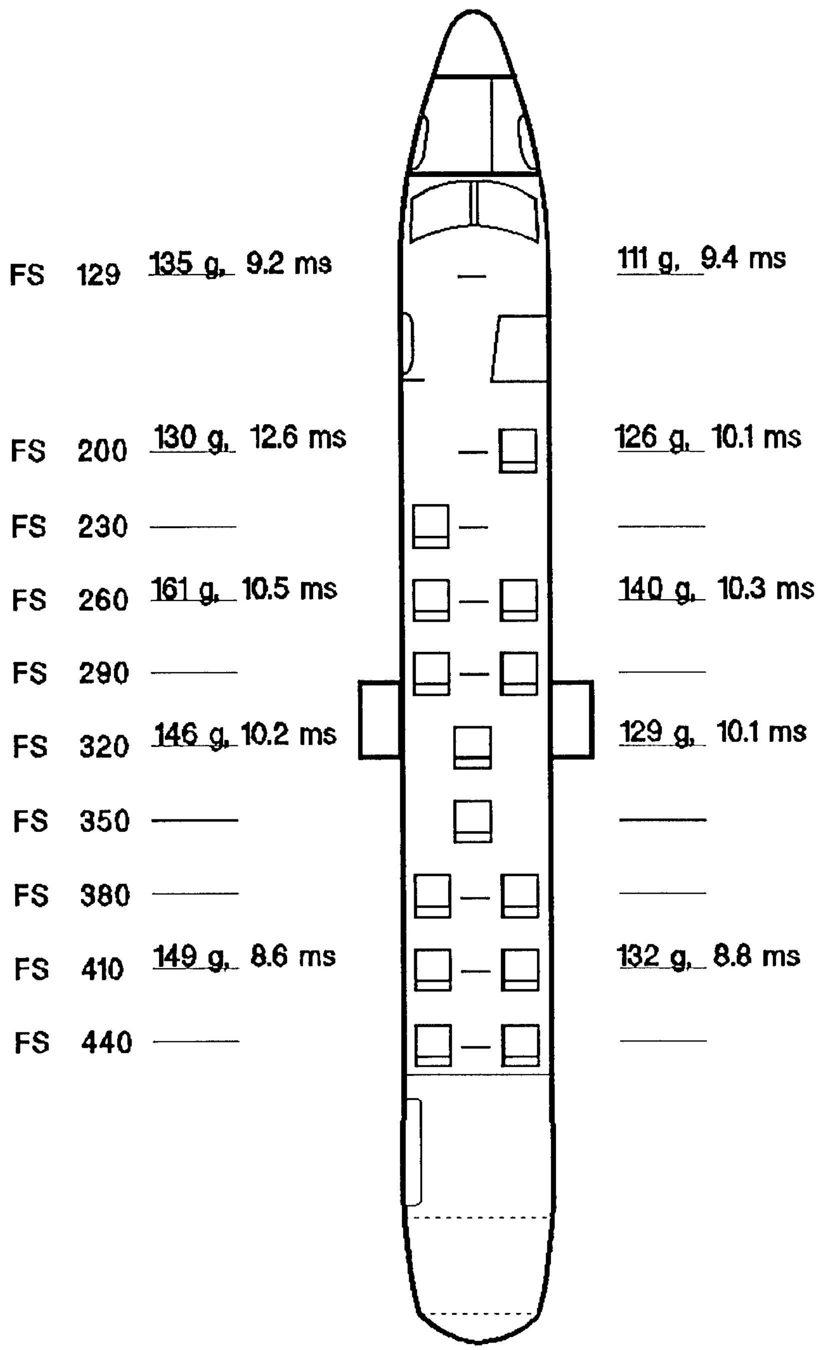


FIGURE 8. SIDE WALL ACCELERATIONS (G_{max})

TABLE 6. SIDE WALL SEAT TRACK ACCELERATIONS

Fuselage Station	G_{peak} (g)	G_{max} (g)	Pulse Duration (msec)
FS 200 P	153	151	10.9
FS 200 C	145	145	9.9
FS 260 P	170	163	9.9
FS 260 C	161	147	9.9
FS 290 P	166	160	8.7
FS 290 C	154	148	8.6
FS 410 P	151	155	8.2
FS 410 C	146	149	8.2

NOTE: P = Pilot/left side, C = Copilot/right side

TABLE 7. SIDE WALL ACCELERATIONS

Fuselage Station	G_{peak} (g)	G_{max} (g)	Pulse Duration (msec)
FS 129 P	144	135	9.2
FS 129 C	111	111	9.4
FS 200 P	139	130	12.6
FS 200 C	127	126	10.1
FS 260 P	172	161	10.5
FS 260 C	157	140	10.3
FS 320 P	154	146	10.2
FS 320 C	148	129	10.1
FS 410 P	151	149	8.6
FS 410 C	137	132	8.8

NOTE: P = Pilot/left side, C = Copilot/right side

The floor seat track G_{peak} and G_{max} values in table 5 are based on the clipped data. The actual impact G_{peak} and G_{max} values should be slightly higher. Observing the G_{max} mean values of the side wall seat track and the side wall indicates that the fuselage acceleration during the impact was in the range of 140-160 g's. From tables 5, 6, and 7, the impact pulse duration was in the range of 9-10 milliseconds. This is considered to be a severe but survivable impact [3].

PLATFORM.

The platform data are presented in appendix A, figures A-52 to A-65. The platform accelerations were recorded by two accelerometers mounted underneath the center of the platform. Figure A-64 shows that the impact and rebound accelerations of the platform were about 50 and 52 g's, respectively. The impact load was measured by the 12 load cells that supported the platform. Posttest observation clearly showed that two rows of platform load cells had bottomed out. This might cause the total measured impact load to be less than the actual impact load. The total measured impact load is presented in figure 9.

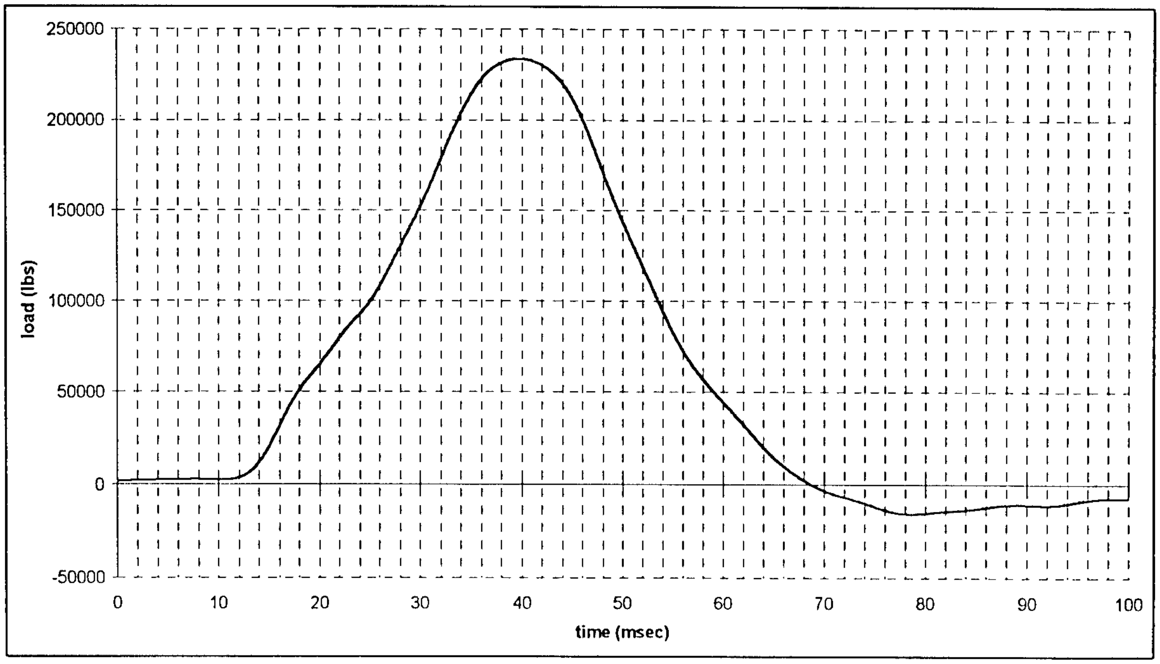


FIGURE 9. PLATFORM TOTAL LOAD

ANTHROPOMORPHIC DUMMIES.

Seven anthropomorphic dummies were used to measure loads and accelerations in their respective lumbar areas for various types of passenger seats during this test. Usable data were not recorded from the dummies in the two WSU energy-absorbing seats due to catastrophic failure of the seats and the mounting systems during the test. The data from the anthropomorphic test dummies are presented in table 8.

TABLE 8. ANTHROPOMORPHIC DUMMY DATA

Fuselage Station and Seat	Lumbar Load (lb)	G_{peak} (g)	G_{max} (g)	Pulse Duration (msec)
WSU - FS 200 C	No Data	No Data	No Data	No Data
WSU - FS 260 P	No Data	No Data	No Data	No Data
PTC - FS 290 C	2302	57	43	44
CAMI - FS 320 CTR	2577	38	34	50
BEECH - FS 350 CTR	2345	66	45	44
PTC - FS 380 P	2304	69	37	50
BEECH - FS 380 C	1774	40	32	61

NOTE: P = Pilot/left side, C = Copilot/right side

Data verification tests conducted at the FAA's Civil Aeromedical Institute showed (CAMI) that the high measured lumbar load of the ATD in the CAMI seat was due to a mechanical malfunction that did not allow the seat to fully stroke as designed.

RESULTS AND DISCUSSION

FUSELAGE STRUCTURE.

EXTERNAL. The Beechcraft 1900C airliner fuselage experienced minimal external deformation during this dynamic drop test. The maximum external deformation was only 1.6 inches at FS 410. This was despite the fact that the fuselage experienced decelerations in the range of 140 to 160 g's with pulse durations in the range of 9 to 10 milliseconds. Only the empennage portion of the fuselage experienced any significant deformation due to the fact that the empennage protruded over the end of the drop test platform at impact. Film analysis showed that the fuselage deformation was minimal during the impact as well as after the test (i.e., the fuselage did not crush and then rebound after the impact). All normal exits and emergency exits were functioning properly after the impact.

INTERNAL. The total weight of the test article was 8475 pounds with the combination of fuselage, seats, dummies, and ballast. Some of the ballast consisted of half-inch steel plates. A concentration of these steel plates (805 pounds) between FS 120 and FS 170 caused excessive deformation of the floor beams at this location as well as at FS 544 where 325 pounds of steel plates were concentrated.

SEATS.

Six distinctly different types of seats comprised the 14 seats which were onboard the test article. The majority of the seats (6) were standard, blue-colored Beechcraft seats which were distributed throughout the airplane (figure 2). Two structurally similar standard, brown-colored Beechcraft seats were onboard. Although the standard seats, both blue and brown, are offered by Beechcraft as standard equipment, most operators opt for PTC Aerospace seats; two PTC seats were onboard for the test. Two experimental Wichita State University energy-absorbing seats, a CAMI energy-absorbing seat, and a Beechcraft seat from a corporate airplane were also on the test article.

Airplane seats should provide enough protection so that the lumbar load on the occupant remains below 1500 pounds. As can be seen from the anthropomorphic test dummy data in table 8, none of the onboard seats provided sufficient protection to insure that the lumbar load remained below 1500 pounds. This was somewhat surprising since previous tests in other airplanes have shown that the CAMI seat was relatively effective in achieving the desired lumbar loads. It was found that the CAMI seat experienced a mechanical malfunction during the test which rendered its energy-absorbing feature inoperative. Likewise, the energy-absorbing feature of the experimental WSU seats was not properly tested as evidenced by the failure of the attachment system. Both PTC Aerospace seats experienced approximately 40 g's and imparted 2303 pounds of lumbar load to the occupants. The corporate Beechcraft seat experienced 45 g's with 2345 pounds of lumbar load on the occupant.

The standard blue Beechcraft seat experienced 32 g's with 1774 pounds of lumbar load on the occupant. Although this seat did not meet the requirement of a maximum of 1500 pounds of lumbar load, its load and g level were significantly lower than the other seats. This could be

attributed to the seat's construction which is of relatively flexible aluminum tubing and a webbed seat pan thereby providing a measure of energy absorption.

HIGH-SPEED FILM DOCUMENTATION.

Twelve high-speed film cameras were employed on this test to record the impact phenomenon. Five cameras were located outside the test article and seven were located inside the test article. Four of the five external cameras provided very good photographic coverage of the test. One external camera failed. Although all seven internal cameras functioned properly, no photographic coverage of the interior was obtained because the flash bulbs which were to illuminate the interior just prior to impact did not ignite until after impact. A failure of the sequencer mechanism was determined to be the cause.

PHOTOGRAPHIC DOCUMENTATION.

The still photographs in this report both prior to and following the drop test were taken with a 35-mm camera. Figures 10 through 15 show the test facility and exterior pictures of the fuselage, both prior to and following the test.

Figures 16 through 18 are interior pictures of the fuselage after the impact. Figures 19 through 21 are pictures of some of the damage to the fuselage floor tracks and side walls as a result of the impact.

Figures 22 through 33 show pre- and posttest views of the various seats used in the test. These include the CAMI seat, the PTC Aerospace seat, the standard Beechcraft seats, and the WSU energy-absorbing seat.

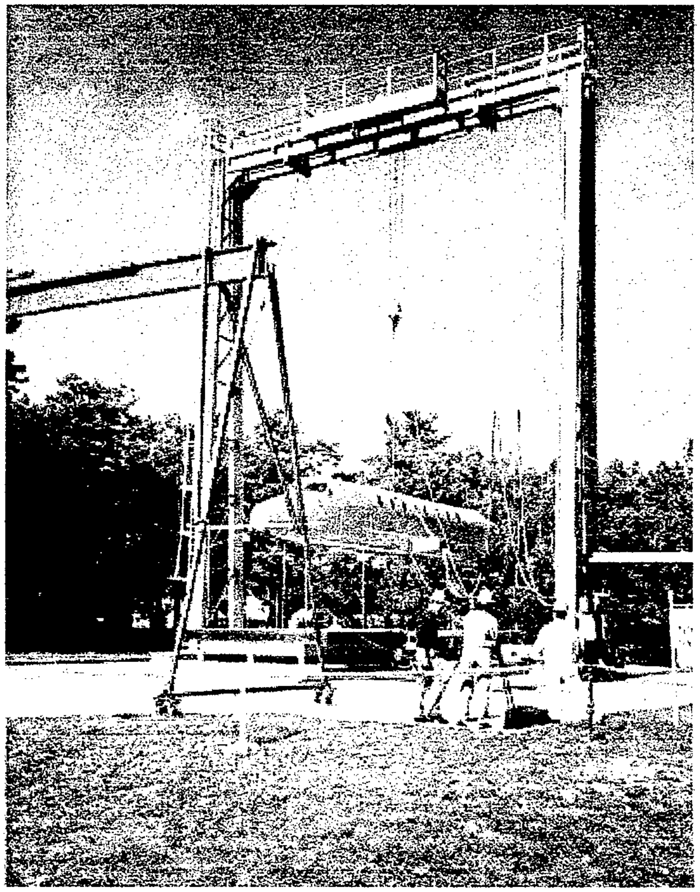


FIGURE 10. DROP TEST FACILITY

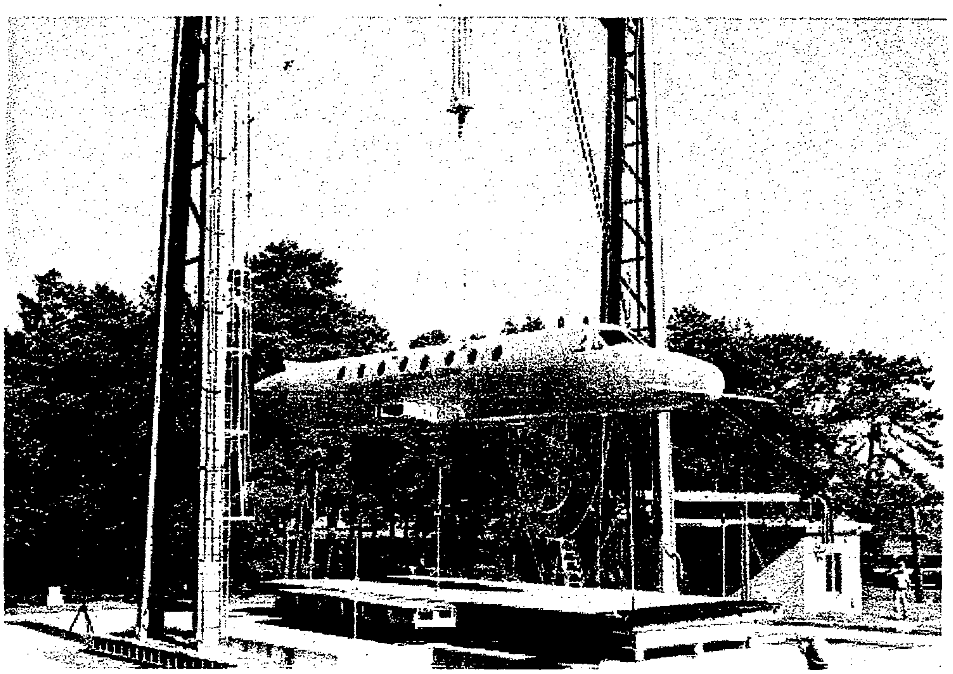


FIGURE 11. FRONT-QUARTER VIEW OF TEST ARTICLE, PRIOR TO IMPACT

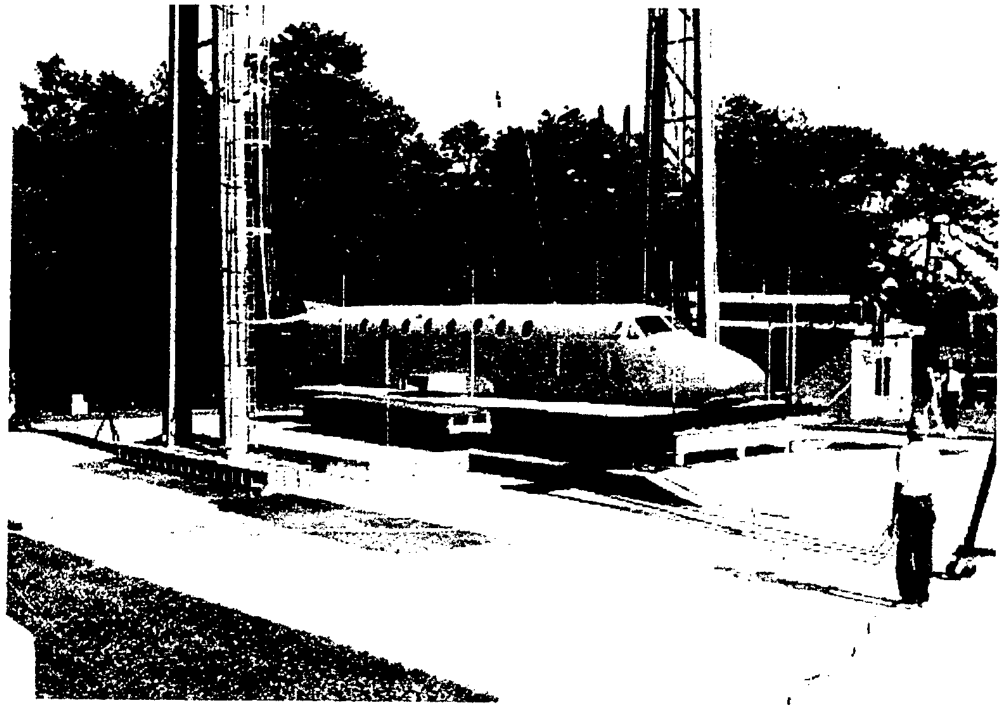


FIGURE 12. FRONT-QUARTER VIEW OF TEST ARTICLE, AFTER IMPACT

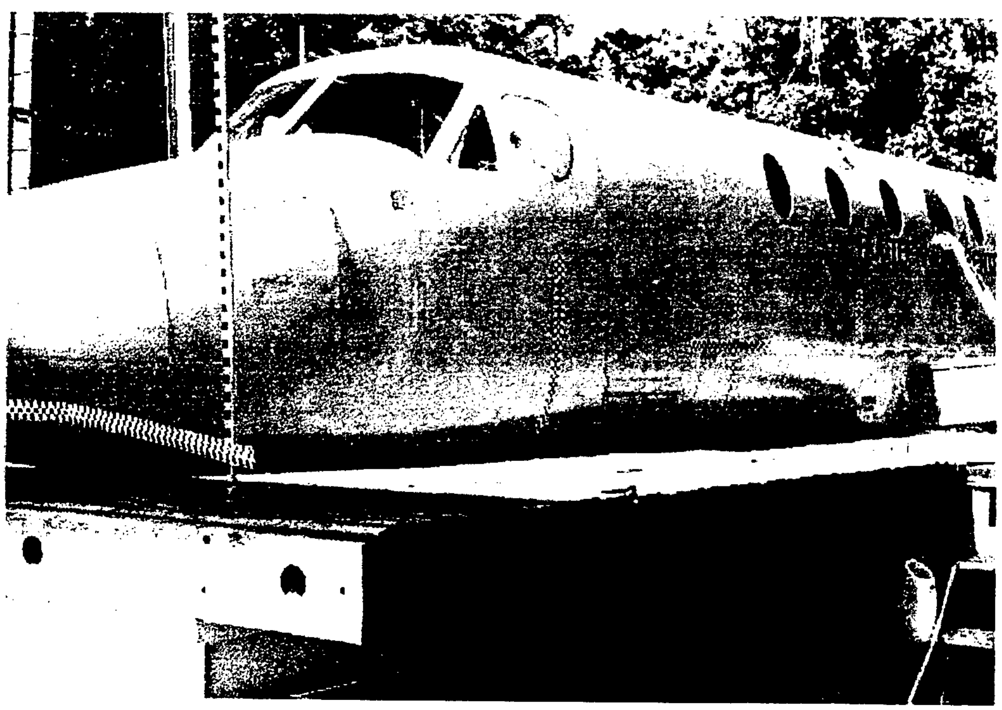


FIGURE 13. FORWARD SECTION OF TEST ARTICLE, AFTER IMPACT

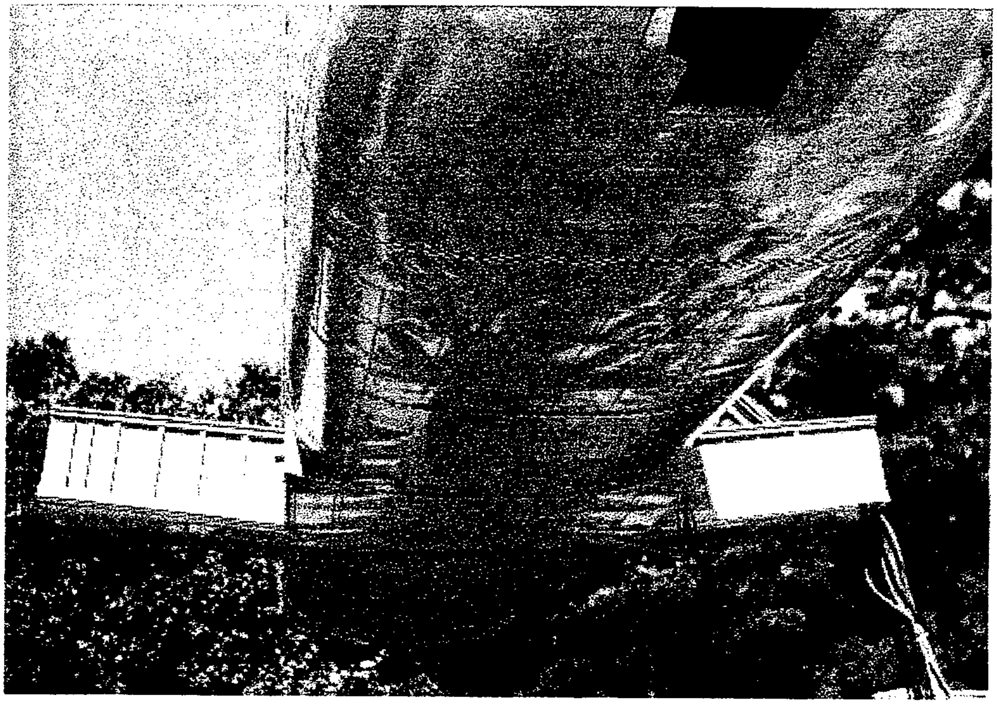


FIGURE 14. UNDERSIDE OF FUSELAGE, AFTER IMPACT

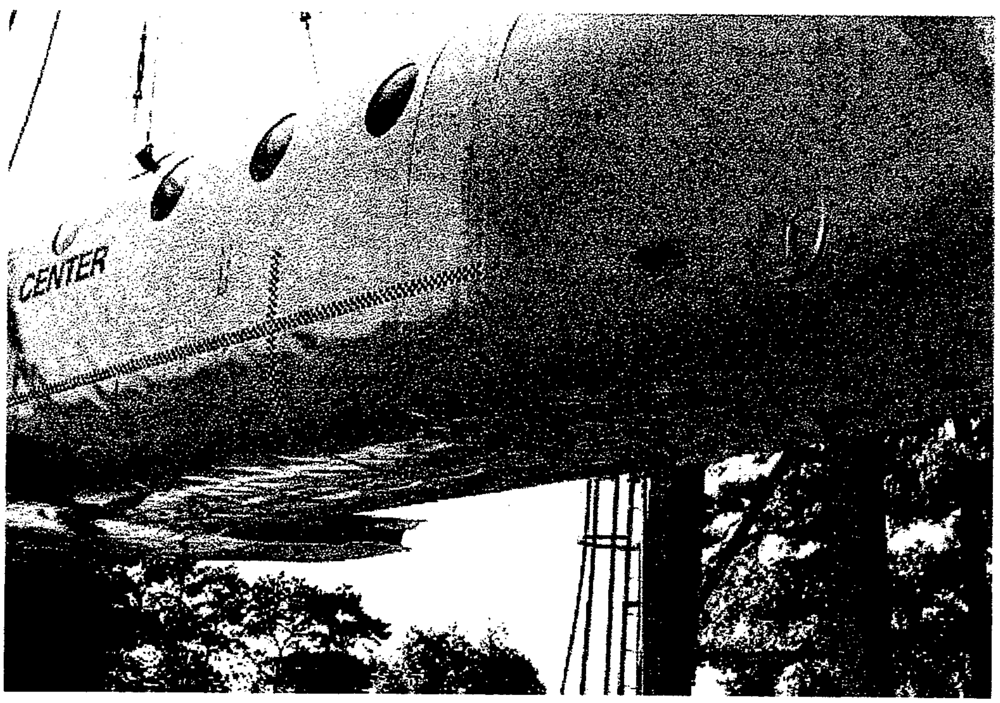


FIGURE 15. UNDERSIDE OF AFT SECTION OF FUSELAGE, AFTER IMPACT

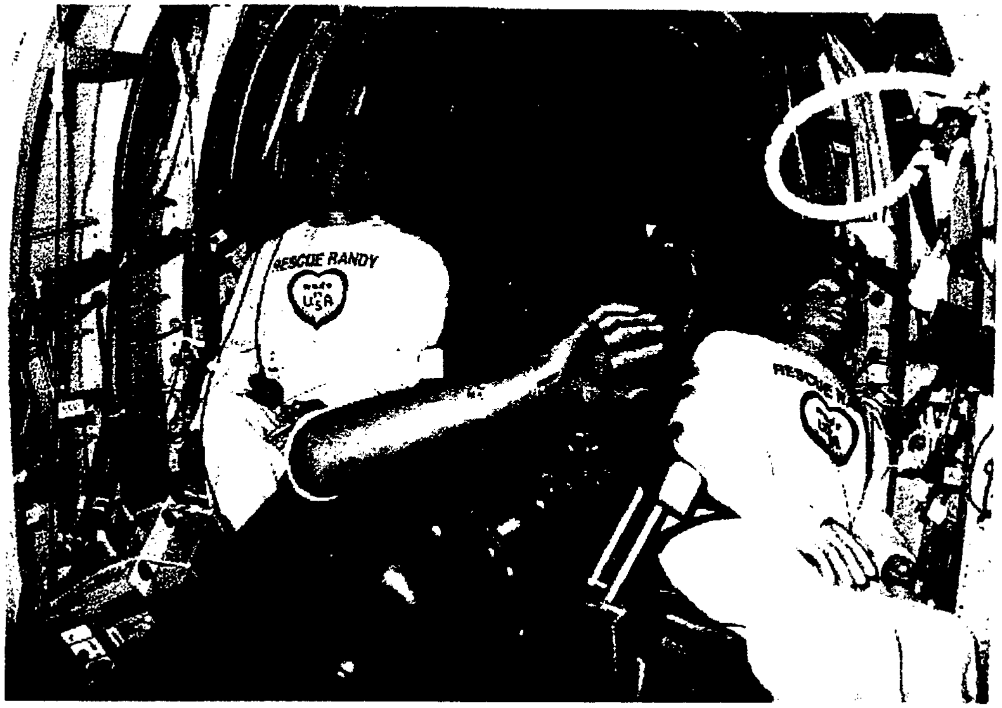


FIGURE 16. FRONT INTERIOR OF TEST ARTICLE, AFTER IMPACT

FIGURE 17. CENTER SECTION OF TEST ARTICLE, AFTER IMPACT

FIGURE 18. AFT SECTION OF TEST ARTICLE, AFTER IMPACT

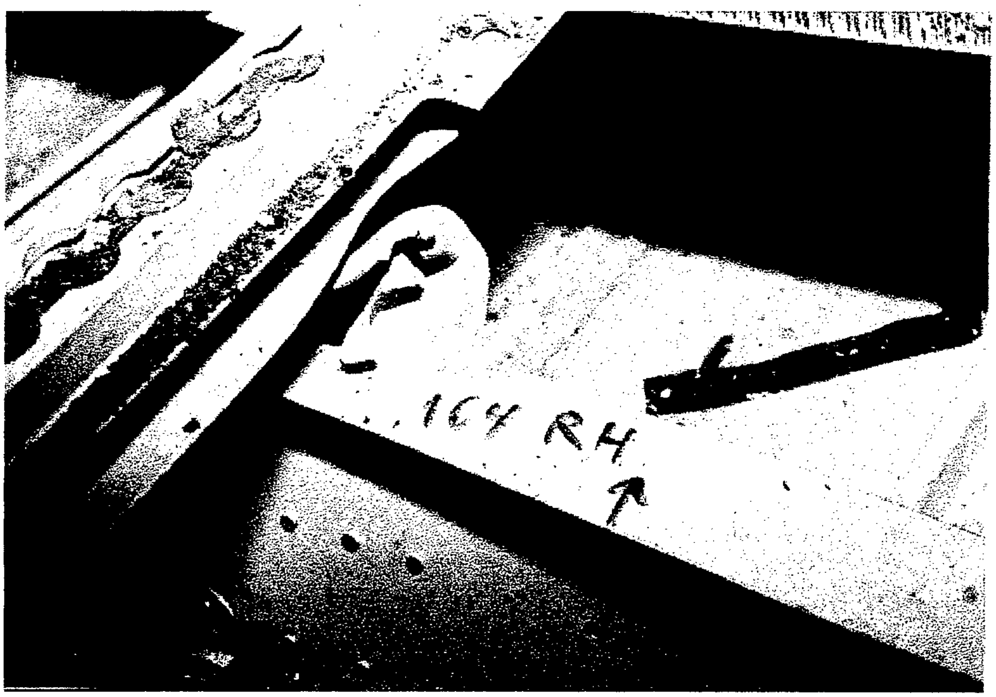


FIGURE 19. UNDERFLOOR BUCKLING R/H SIDE, AFTER IMPACT

FIGURE 20. UNDERFLOOR BUCKLING L/H SIDE, AFTER IMPACT

FIGURE 21. SIDE WALL BUCKLING, AFTER IMPACT

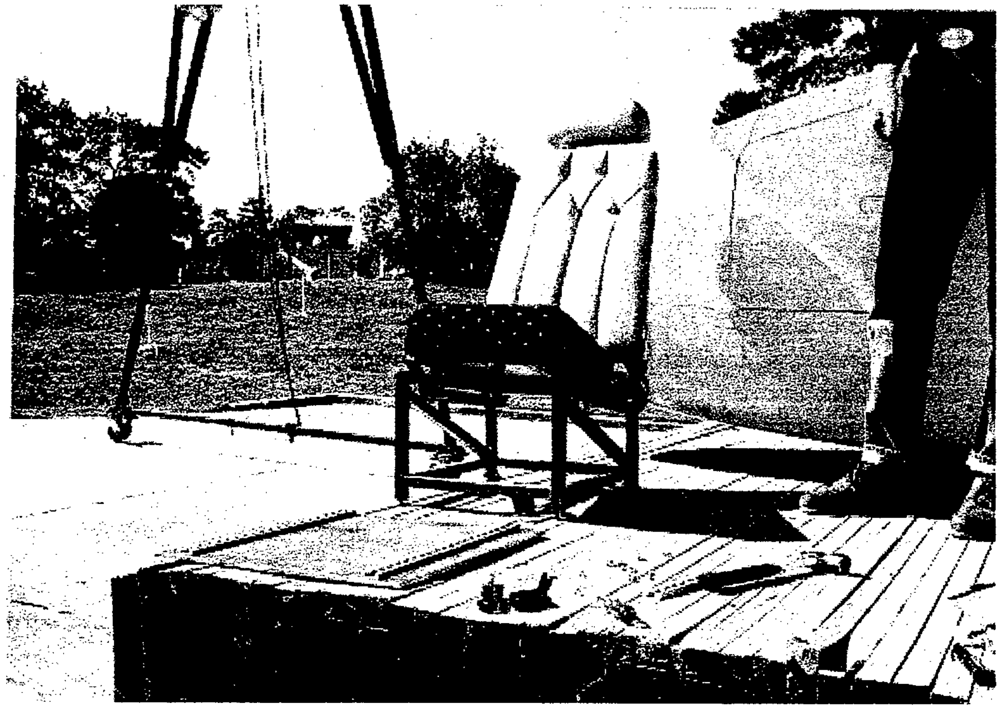


FIGURE 22. CAMI SEAT, PRIOR TO IMPACT

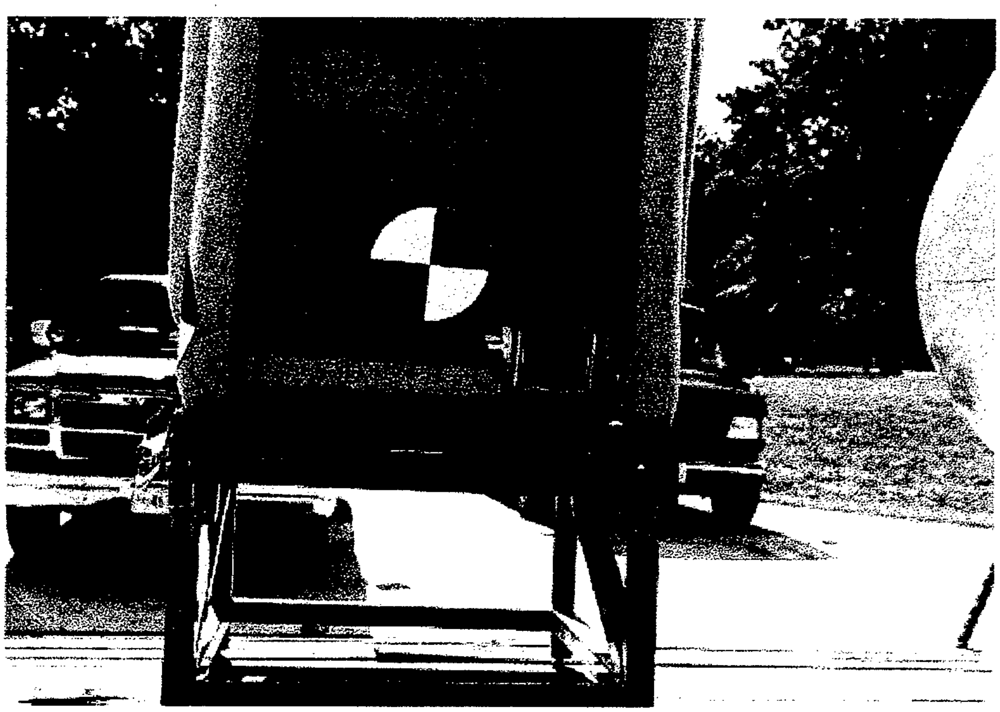


FIGURE 23. CAMI SEAT REAR VIEW, PRIOR TO IMPACT

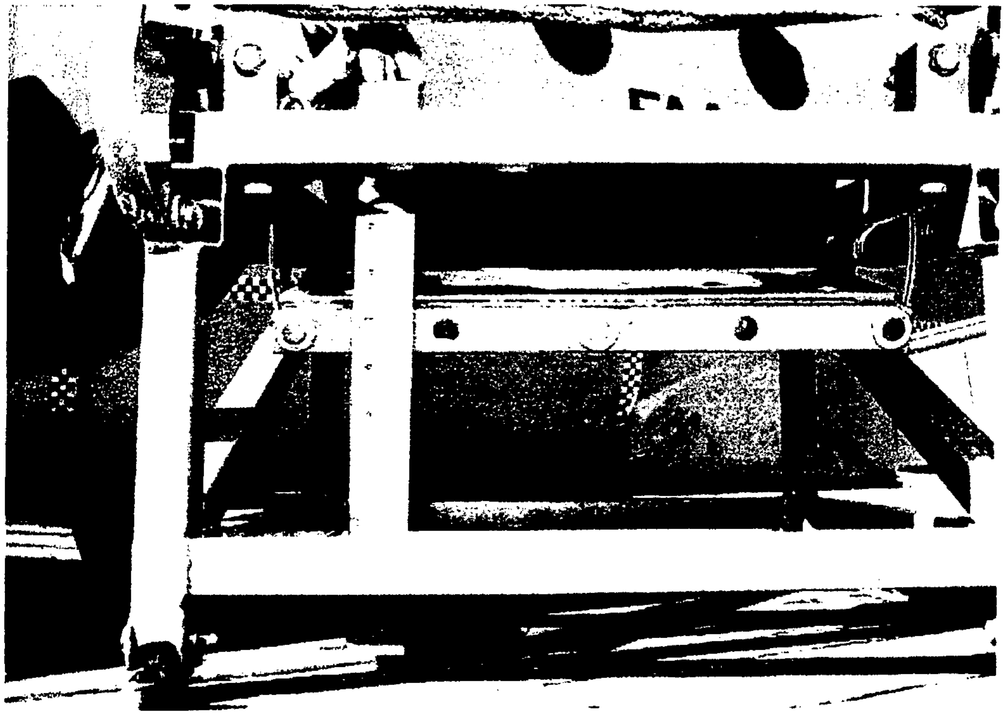


FIGURE 24. CAMI SEAT, SEAT PAN DEFLECTION, AFTER IMPACT

FIGURE 25. PTC AEROSPACE SEAT, PRIOR TO IMPACT

FIGURE 26. PTC SEAT, AFTER IMPACT

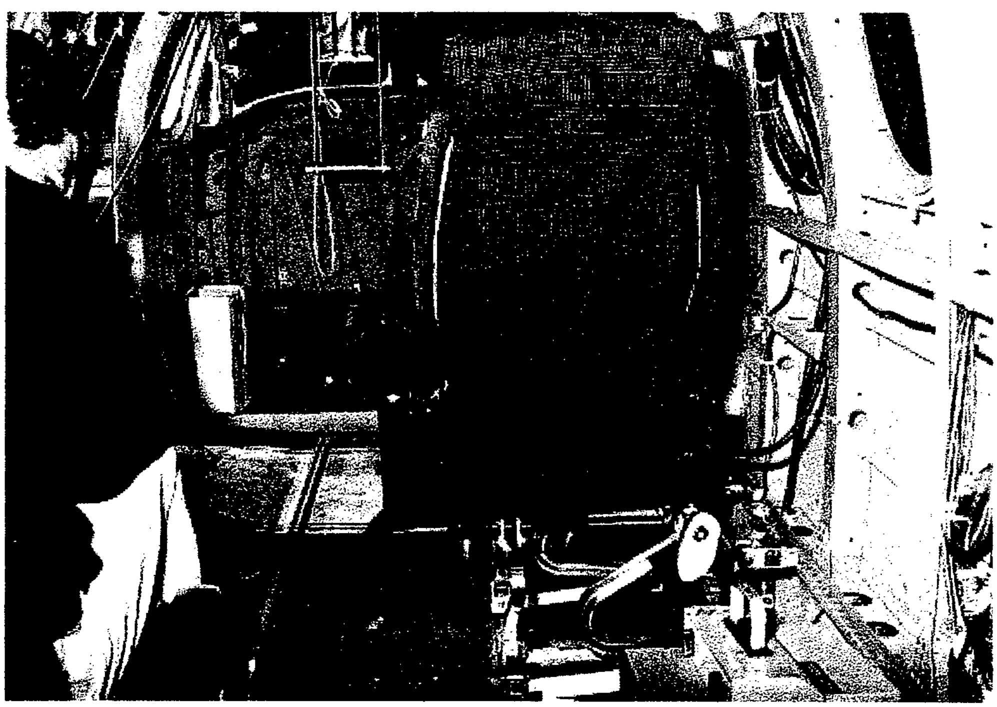


FIGURE 27. REAR VIEW, WSU SEAT, PRIOR TO IMPACT

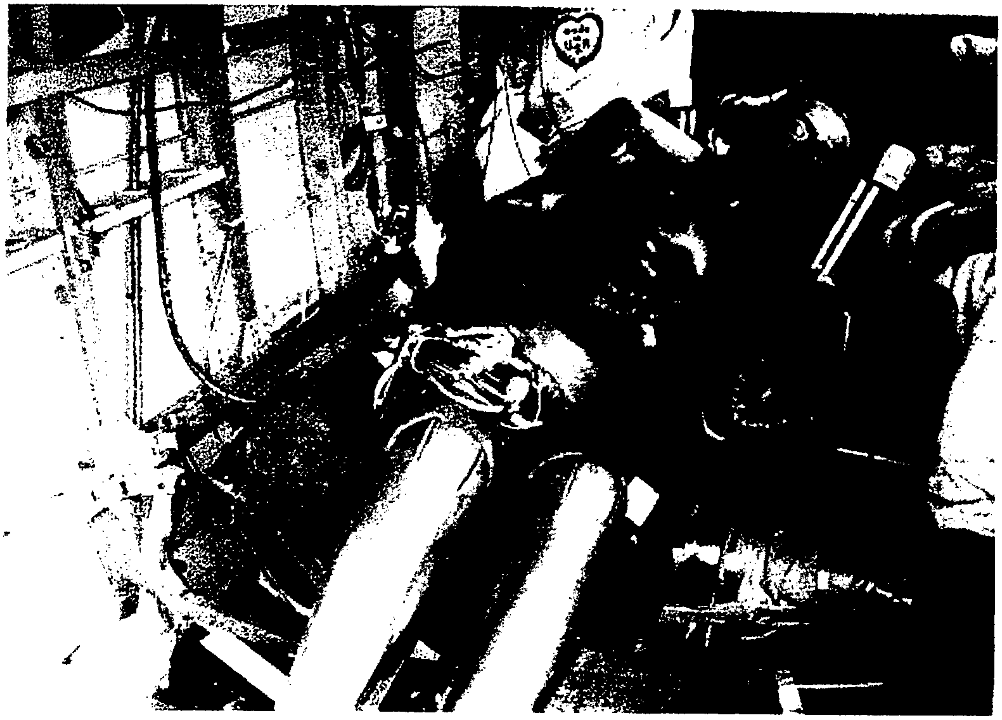


FIGURE 28. FRONT VIEW, WSU SEAT, AFTER IMPACT

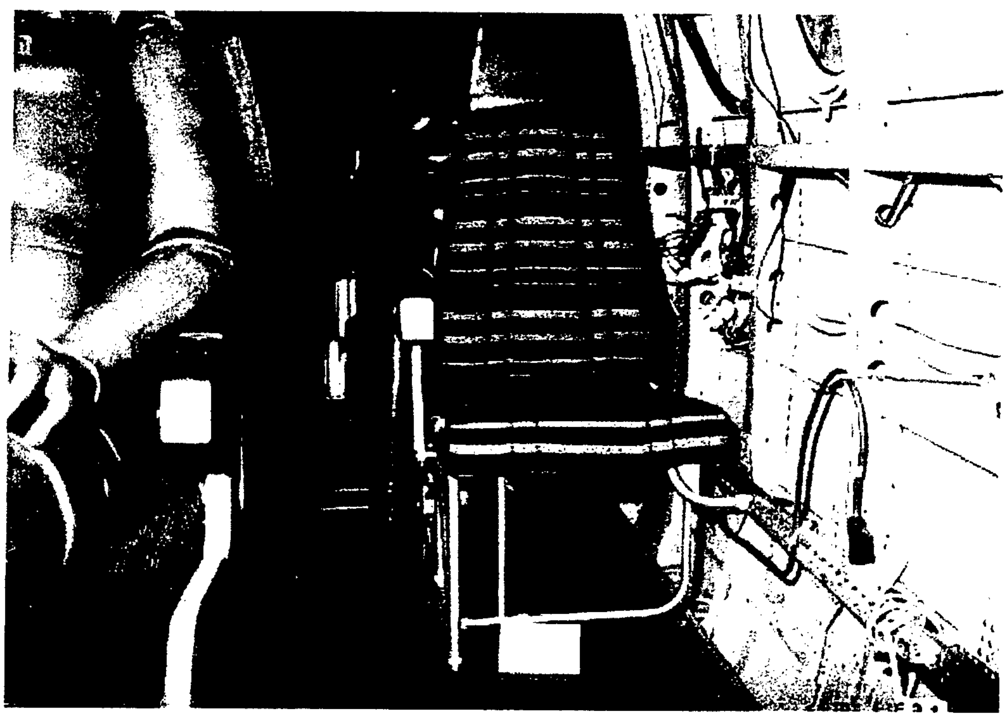


FIGURE 29. STANDARD BEECHCRAFT SEAT (BLUE), PRIOR TO IMPACT

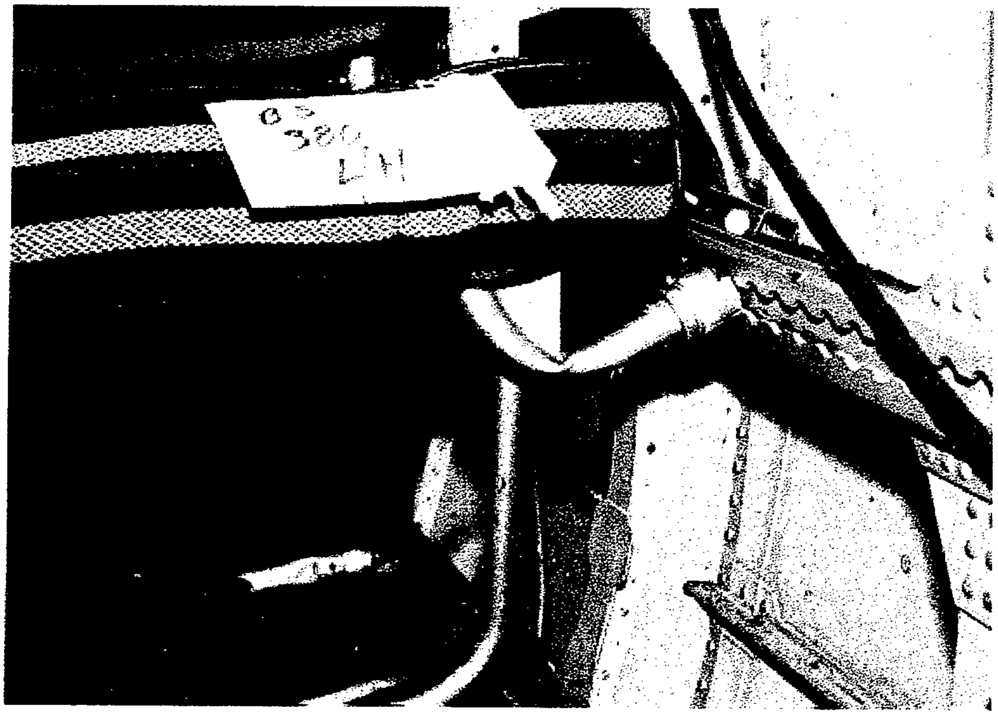


FIGURE 30. STANDARD BEECHCRAFT SEAT (BLUE), AFTER IMPACT

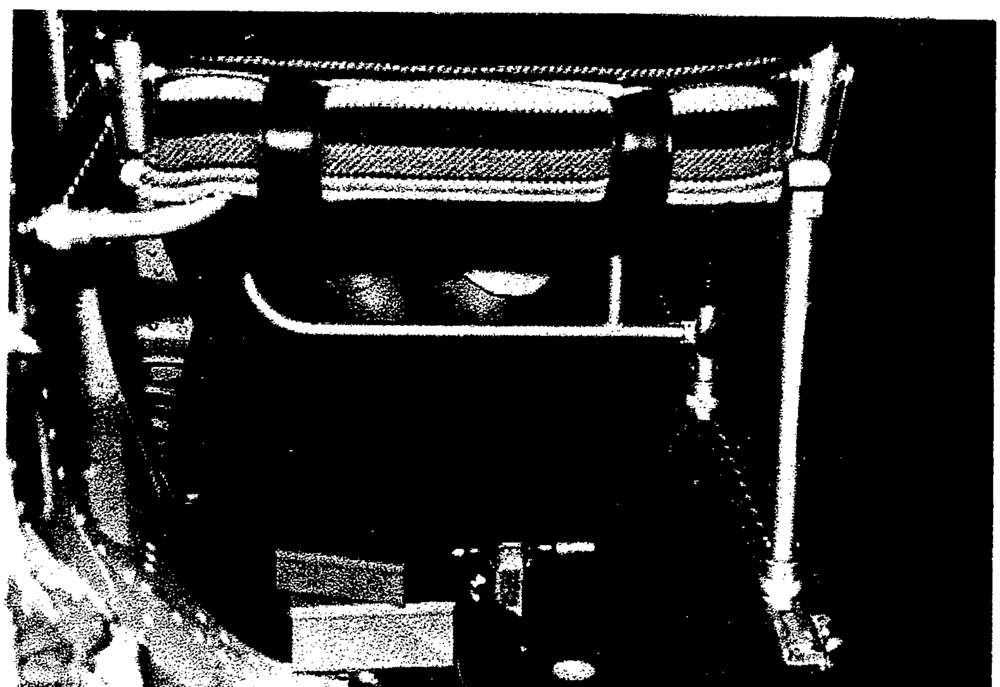


FIGURE 31. STANDARD BEECHCRAFT SEAT (BROWN), PRIOR TO IMPACT

FIGURE 32. STANDARD BEECHCRAFT SEATS (BROWN), AFTER IMPACT

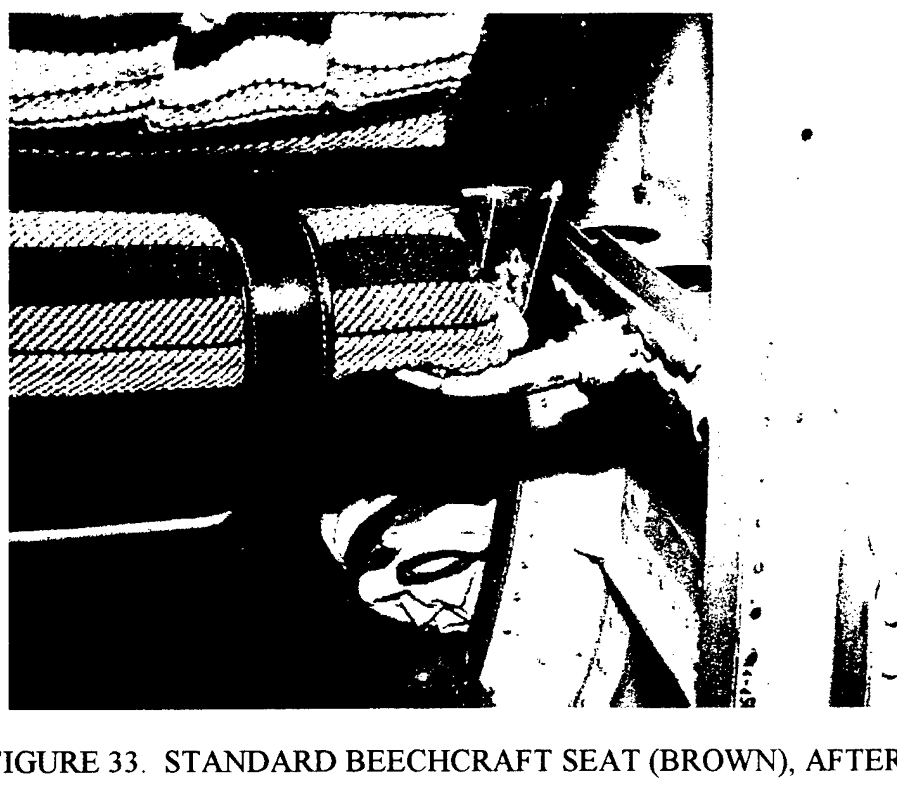


FIGURE 33. STANDARD BEECHCRAFT SEAT (BROWN), AFTER IMPACT

CONCLUDING REMARKS

1. The Beechcraft 1900C test article was dropped from a height of 11′ 2″ with an impact velocity of 26.8 ft/sec.

2. The fuselage experienced an impact in the range of 140-160 g's, with an impact pulse duration of 9-10 ms.

3. The simulated occupants experienced g levels in the range of 32-45 g's with a pulse duration of 44-61 ms. This is considered to be a severe but definitely survivable impact.

4. The fuselage structure maintained a habitable environment during and after the impact.

5. The seat tracks remained attached to the floor along the entire length of the fuselage. This applied to both the side wall and floor track on both sides of the airplane.

6. All standard seats (i.e., Beechcraft seats and PTC Aerospace seats) remained in the seat tracks in their preimpact locations.

7. The exit doors remained operable after the impact, and both emergency exits were functional.

8. None of the anthropomorphic test dummies had a lumbar load below the recommended maximum of 1500 pounds.

REFERENCES

1. Aircraft Safety Research Plan, November 1991, Federal Aviation Administration Technical Center, Atlantic City International Airport, NJ 08405.

2. Vertical Drop Test of a Metro III Aircraft, DOT/FAA/CT-93/1. June 1993, Federal Aviation Administration Technical Center, Atlantic City International Airport, NJ 08405.

3. Aircraft Crash Survival Design Guide, Volume II. December 1989, Simula Inc., Phoenix, AZ, 85044.

APPENDIX A—FILTERED TEST DATA

FLOOR SEAT TRACK DATA (FIGURE A-1 TO FIGURE A-14)

WALL SEAT TRACK DATA (FIGURE A-15 TO FIGURE A-24)

WALL DATA (FIGURE A-25 TO FIGURE A-34)

ANTHROPOMORPHIC DUMMY AND SEAT PAN DATA (FIGURE A-35 TO FIGURE A-51)

VELOCITY AND PLATFORM DATA (FIGURE A-52 TO FIGURE A-67)

FLOOR SEAT TRACK DATA

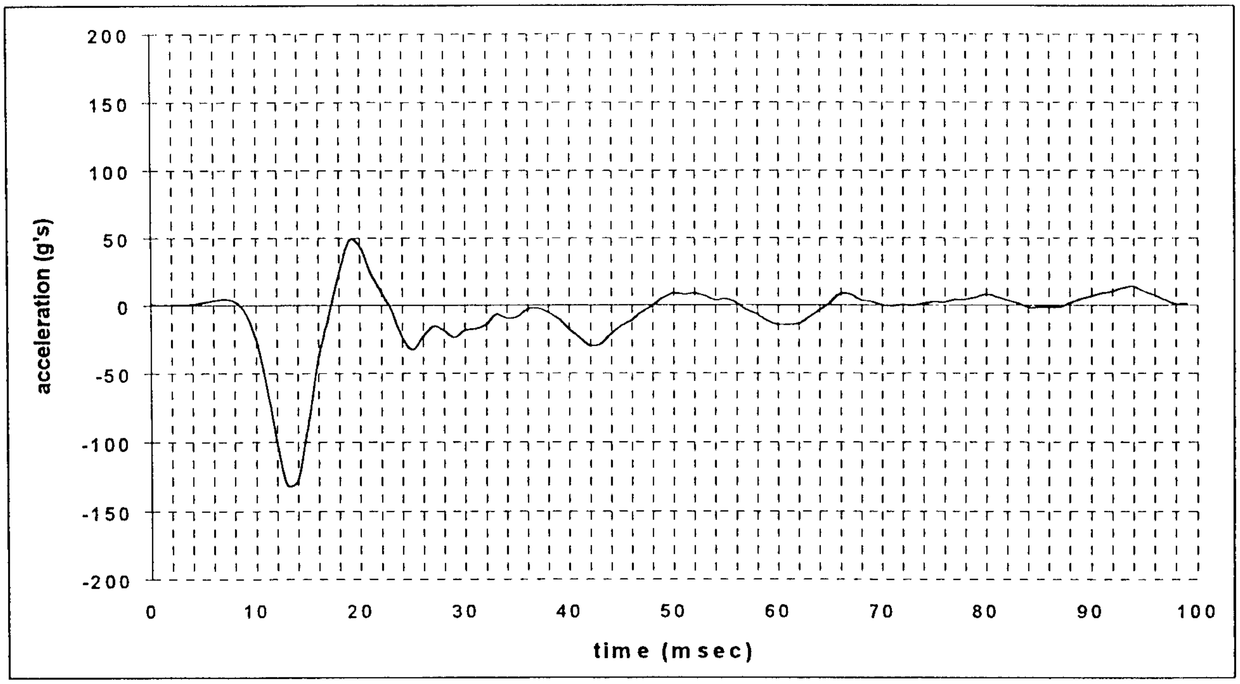


FIGURE A-1. FS 129 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

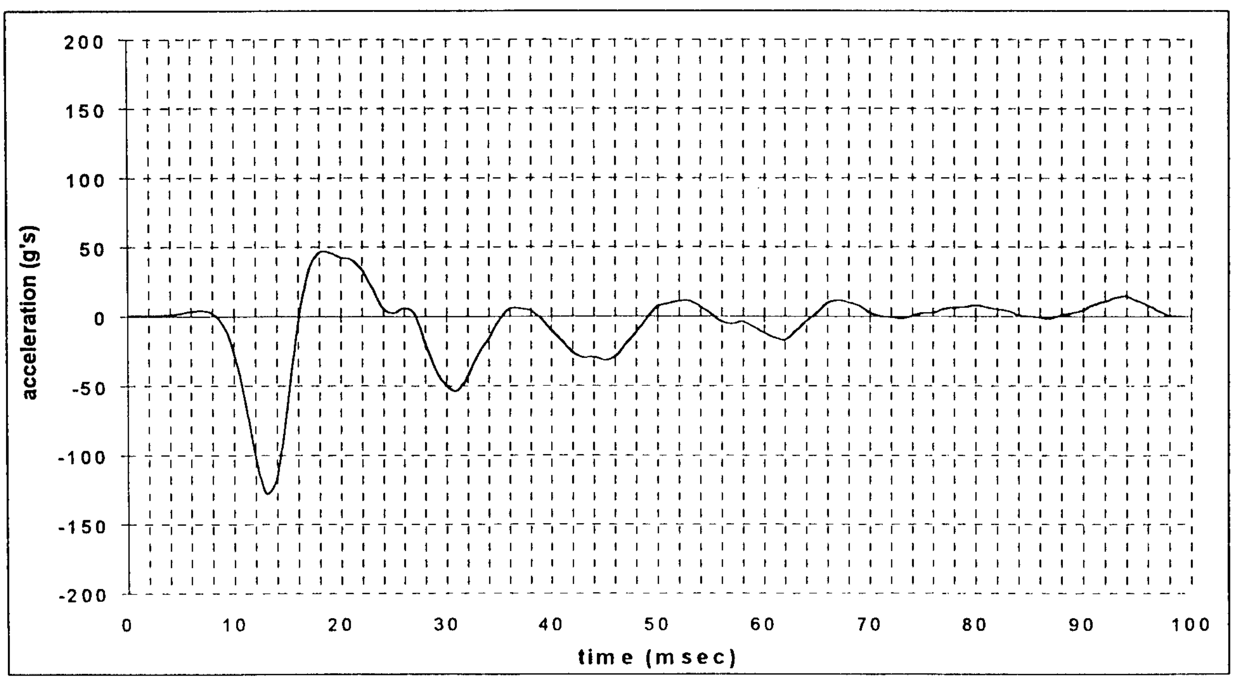


FIGURE A-2. FS 129 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

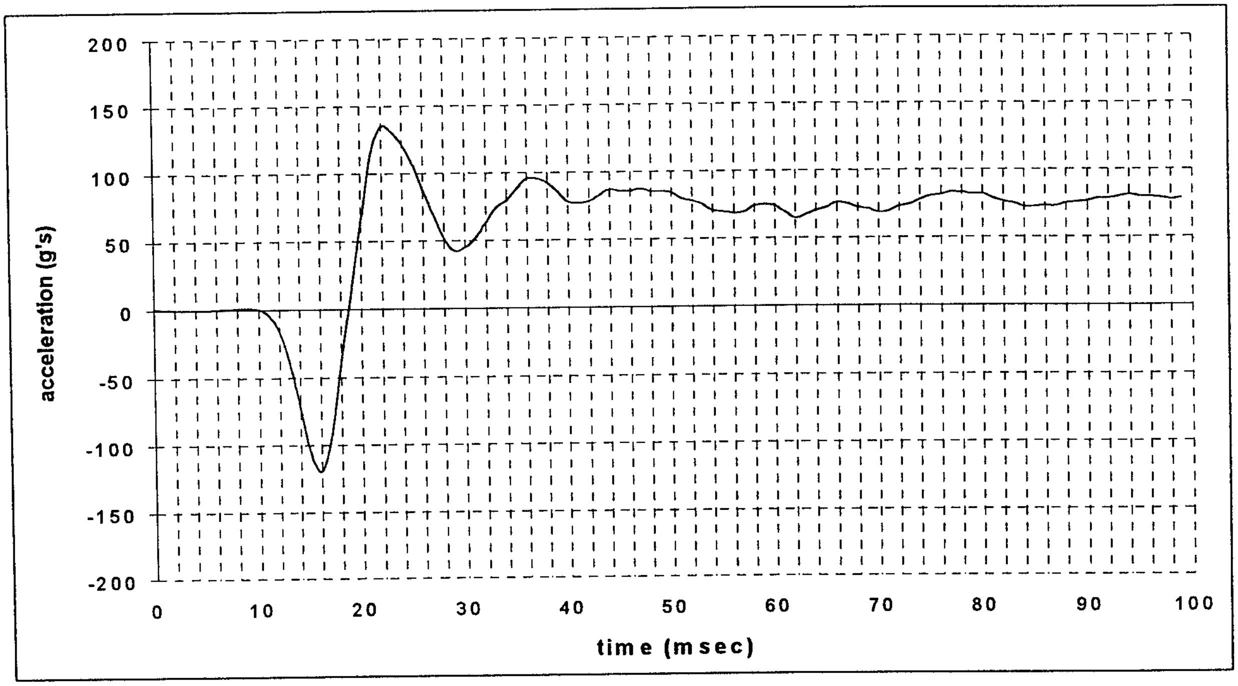


FIGURE A-3. FS 200 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

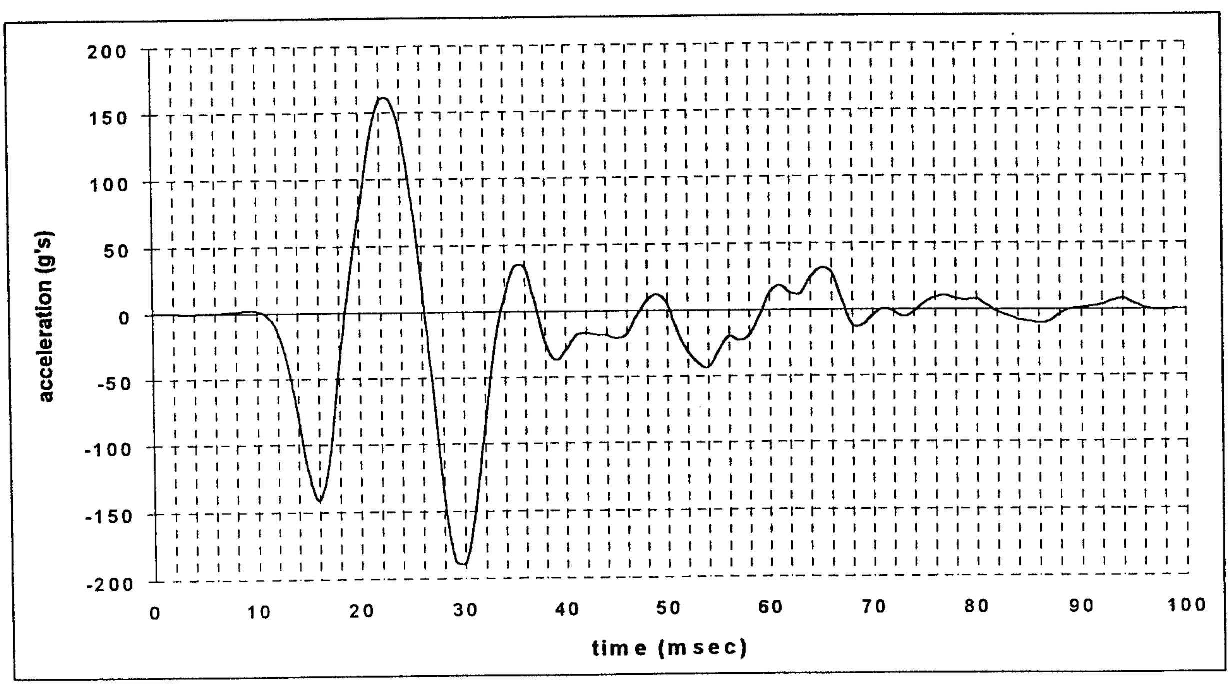


FIGURE A-4. FS 200 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

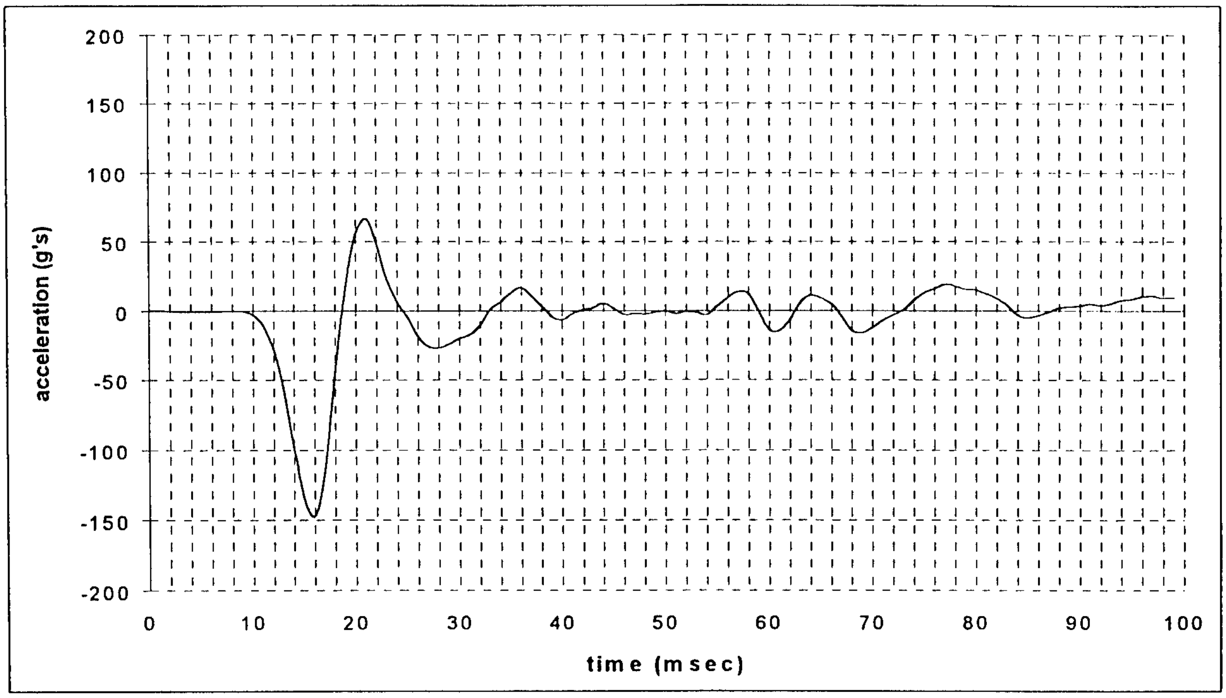


FIGURE A-5. FS 260 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

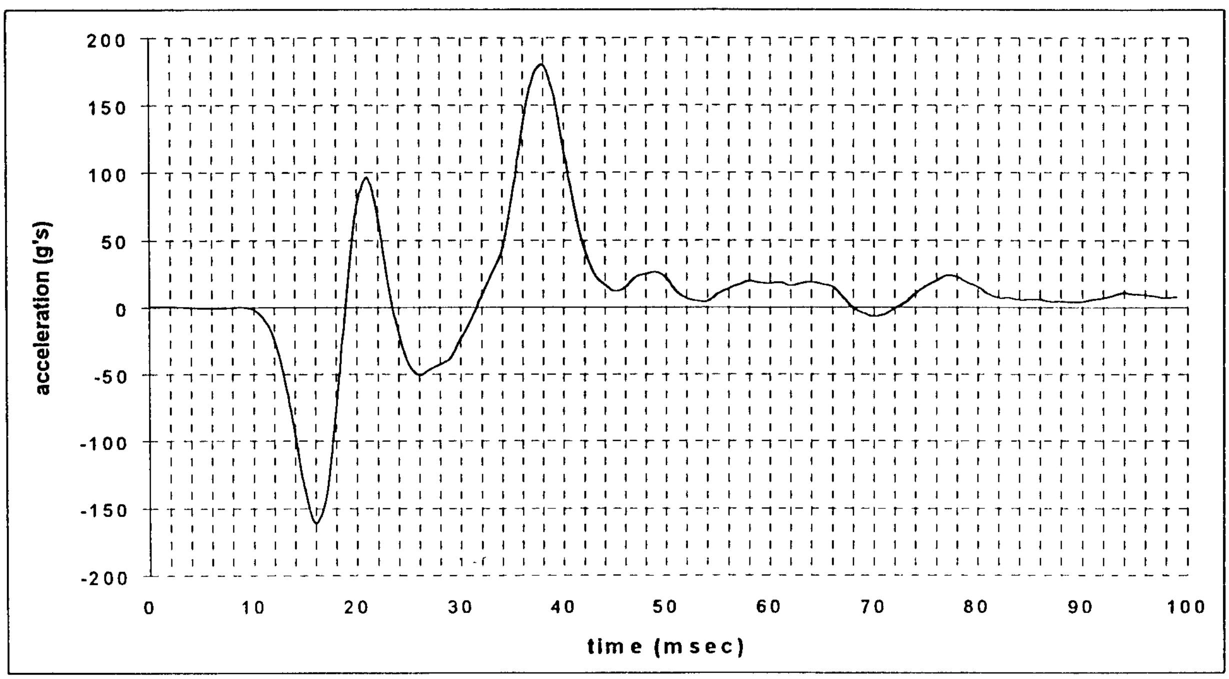


FIGURE A-6. FS 260 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

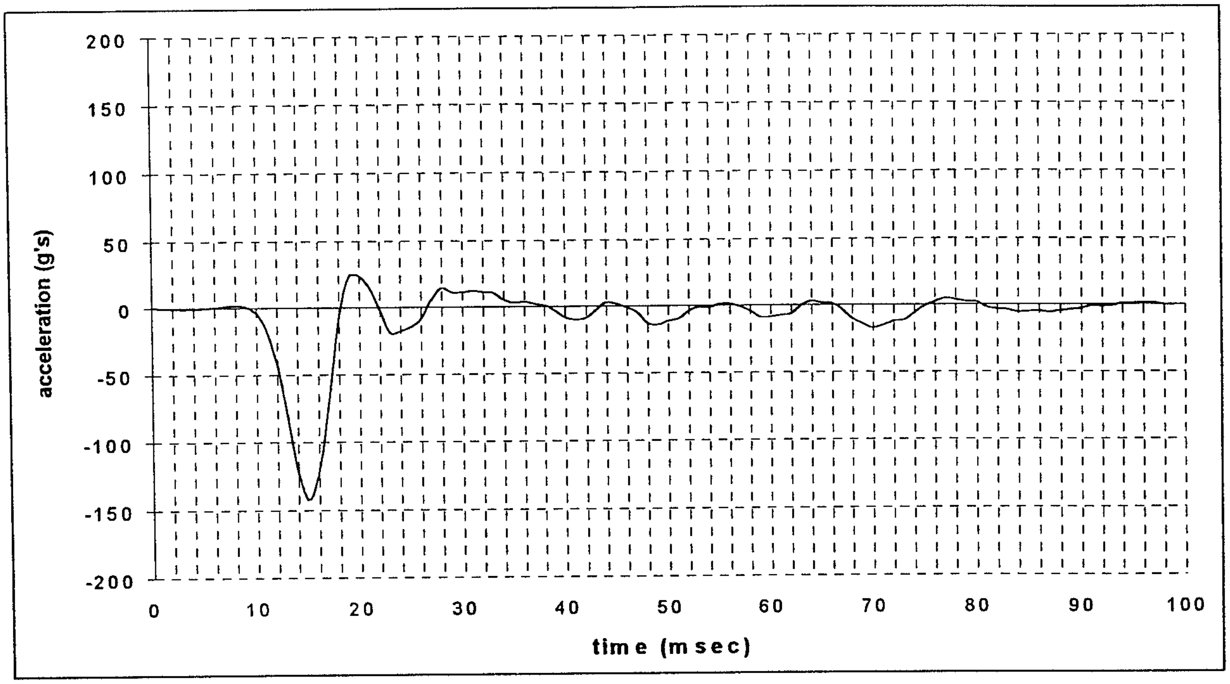


FIGURE A-7. FS 290 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

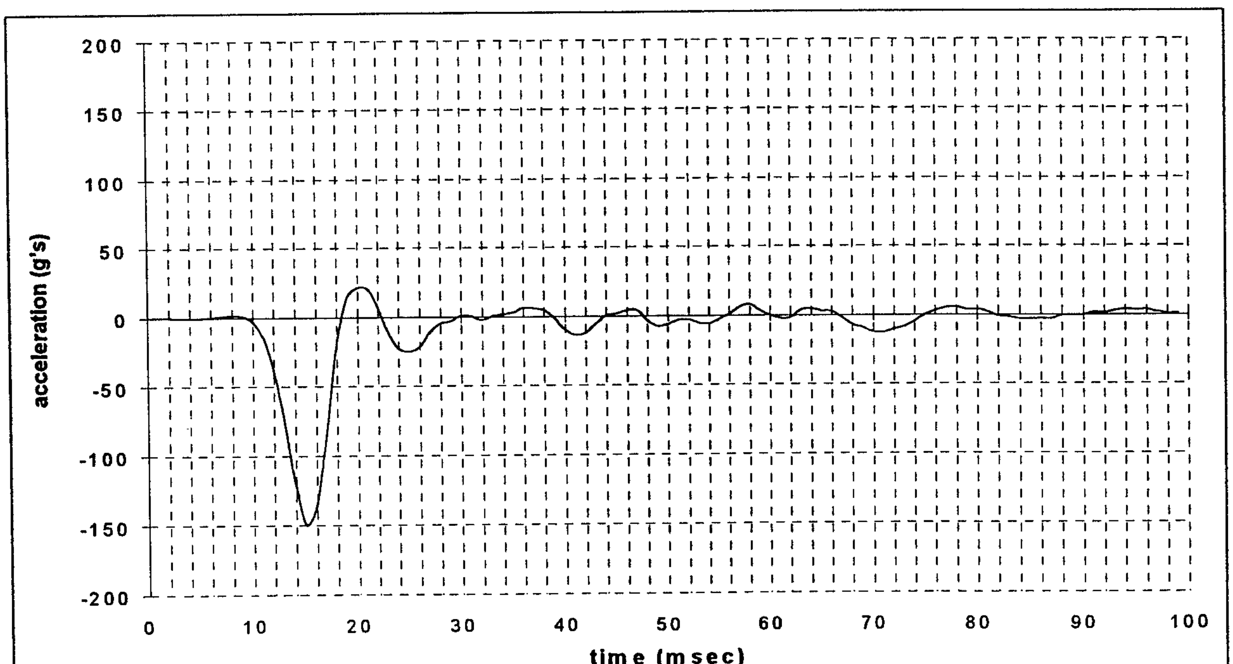


FIGURE A-8. FS 290 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

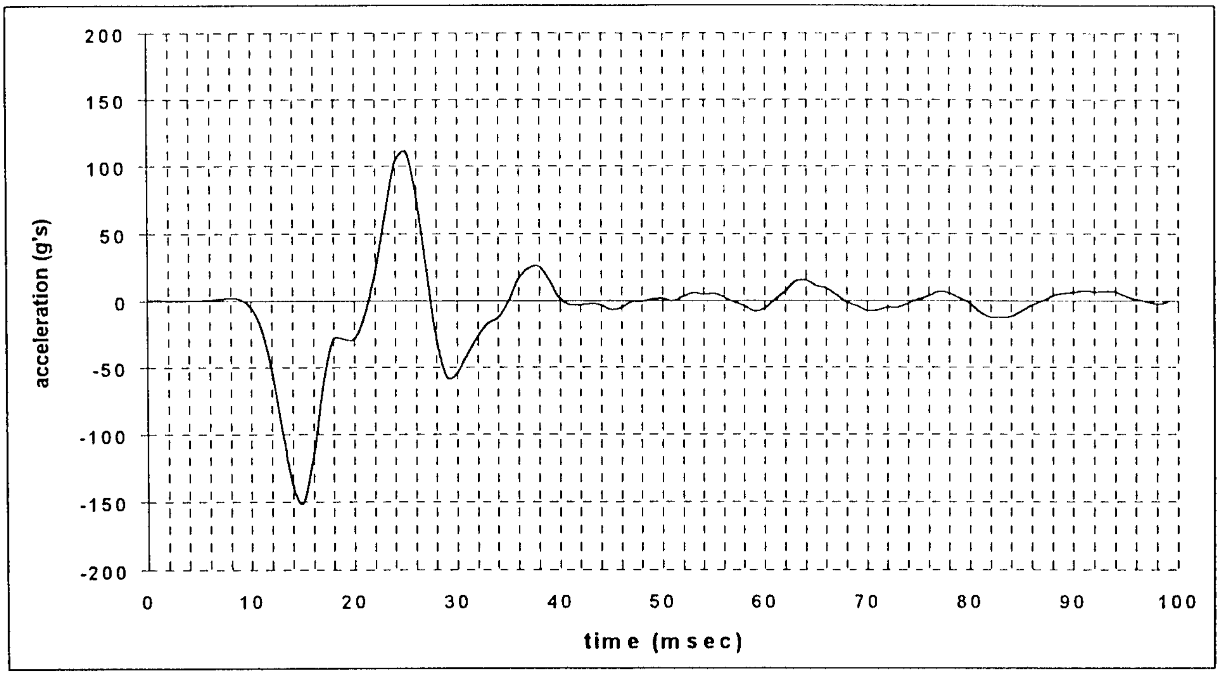


FIGURE A-9. FS 320 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

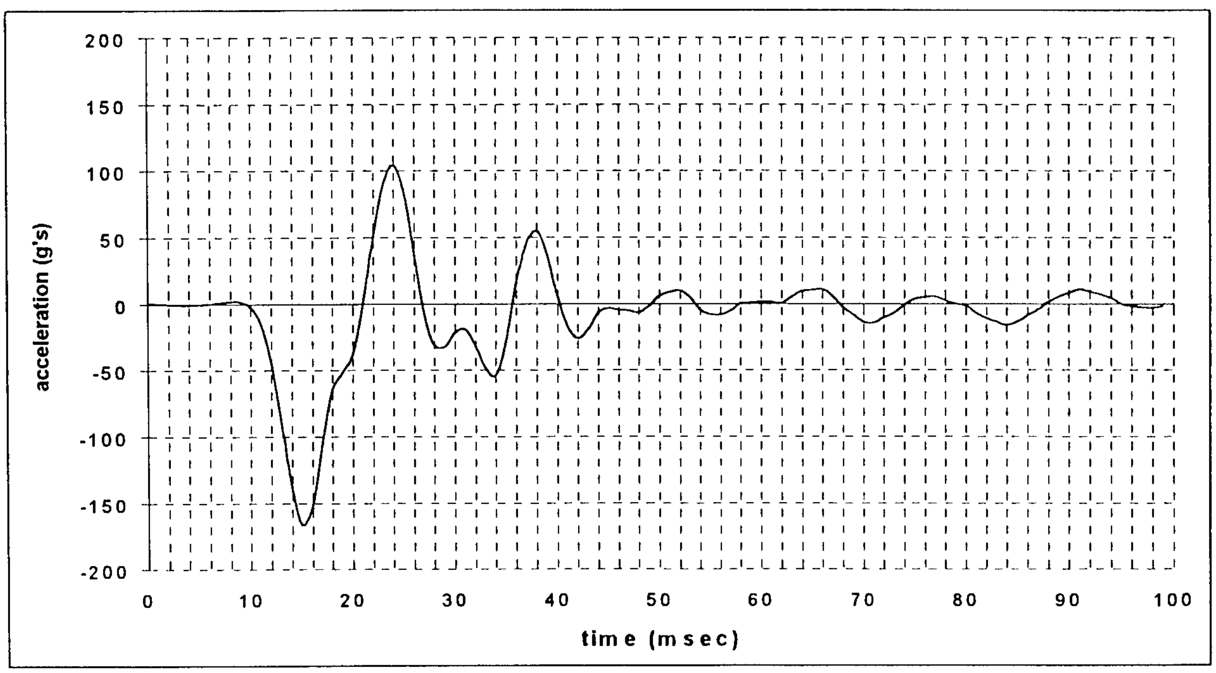


FIGURE A-10. FS 320 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

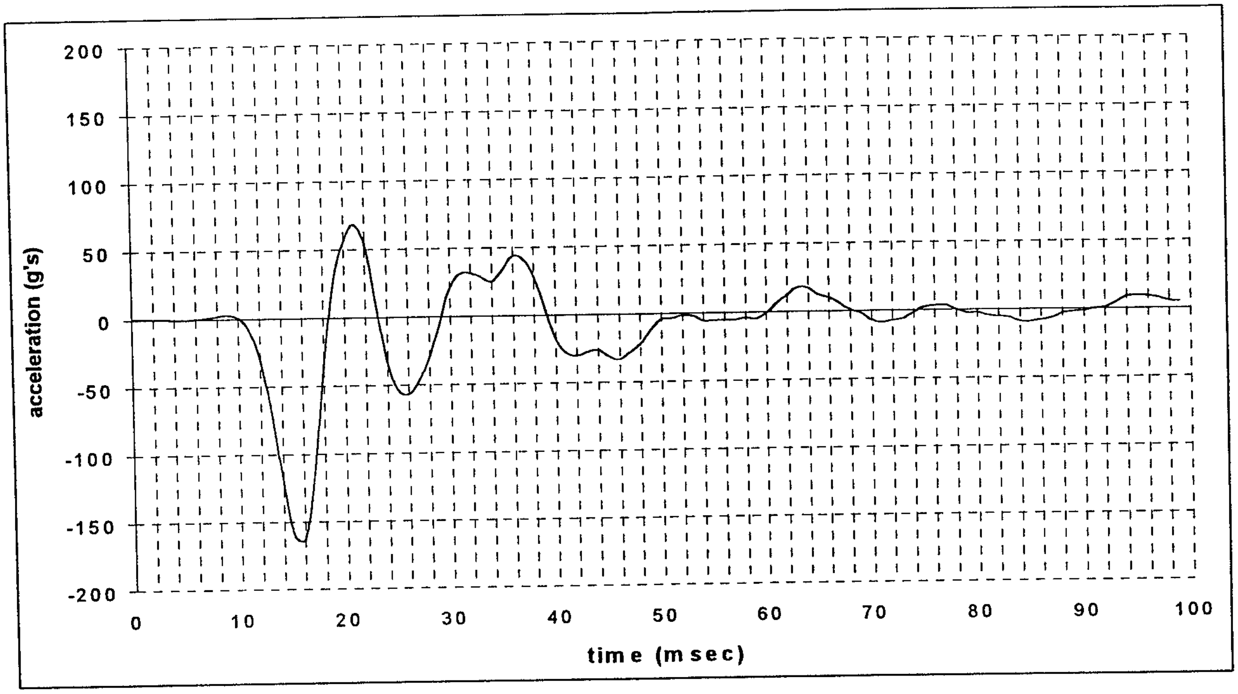


FIGURE A-11. FS 350 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

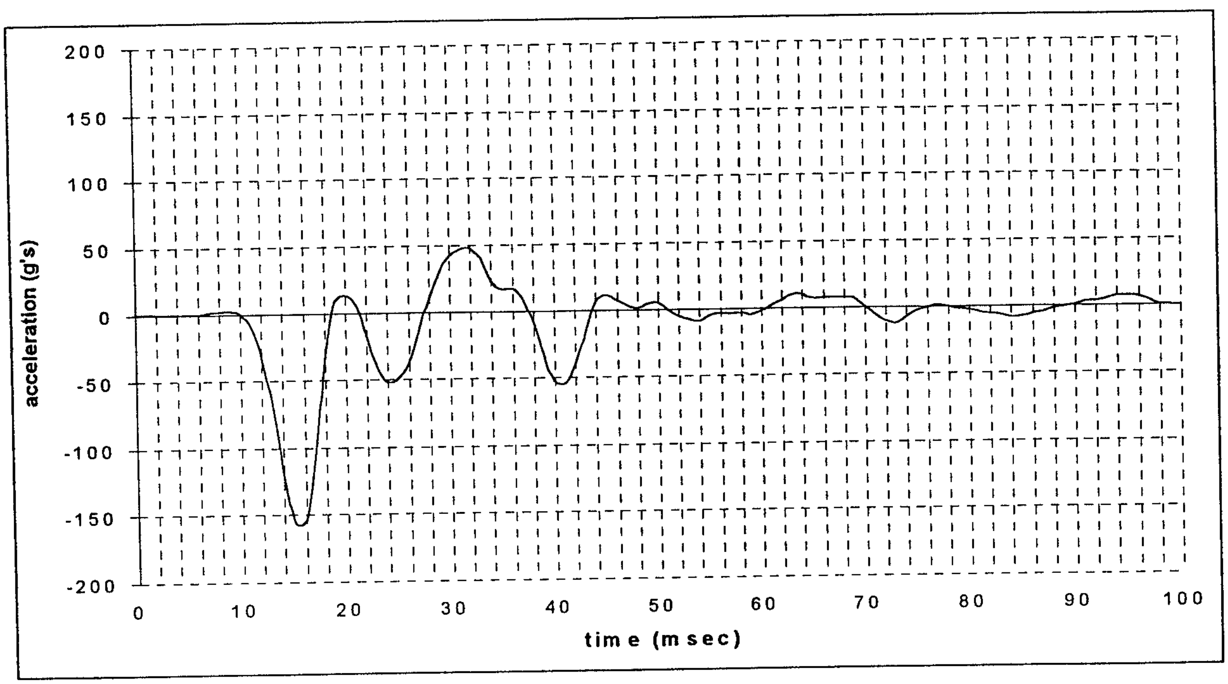


FIGURE A-12. FS 350 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

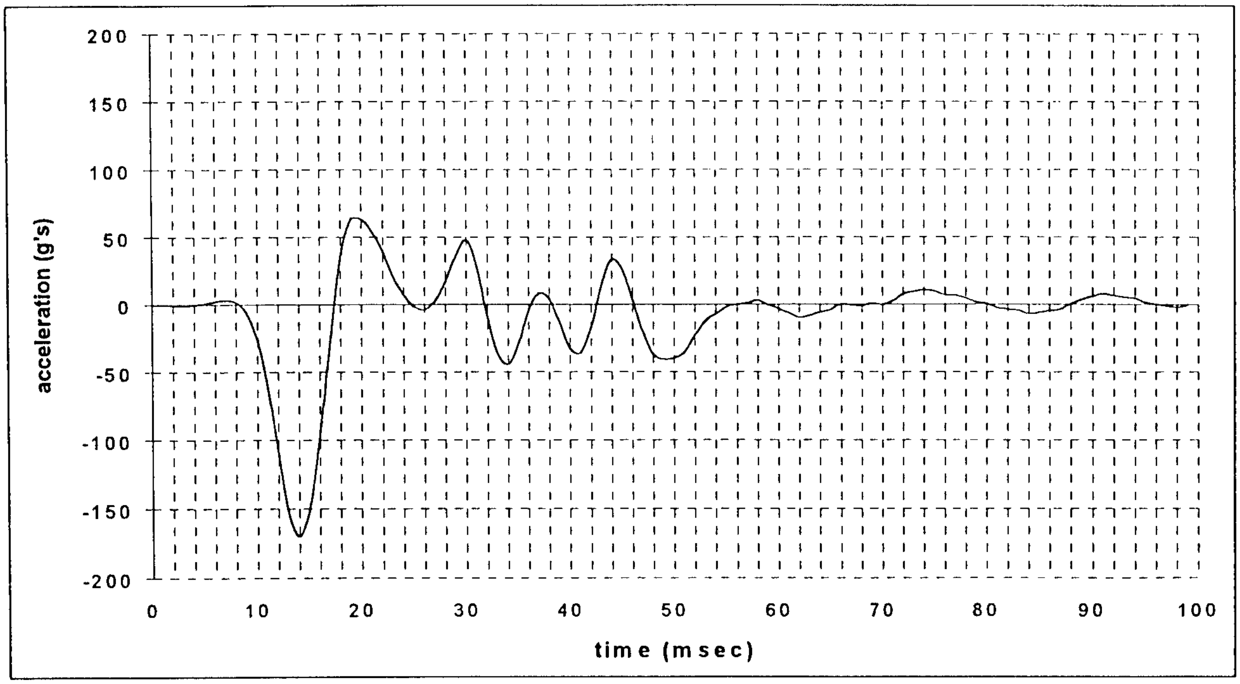


FIGURE A-13. FS 410 FLOOR, LEFT SEAT TRACK VERTICAL ACCELERATION

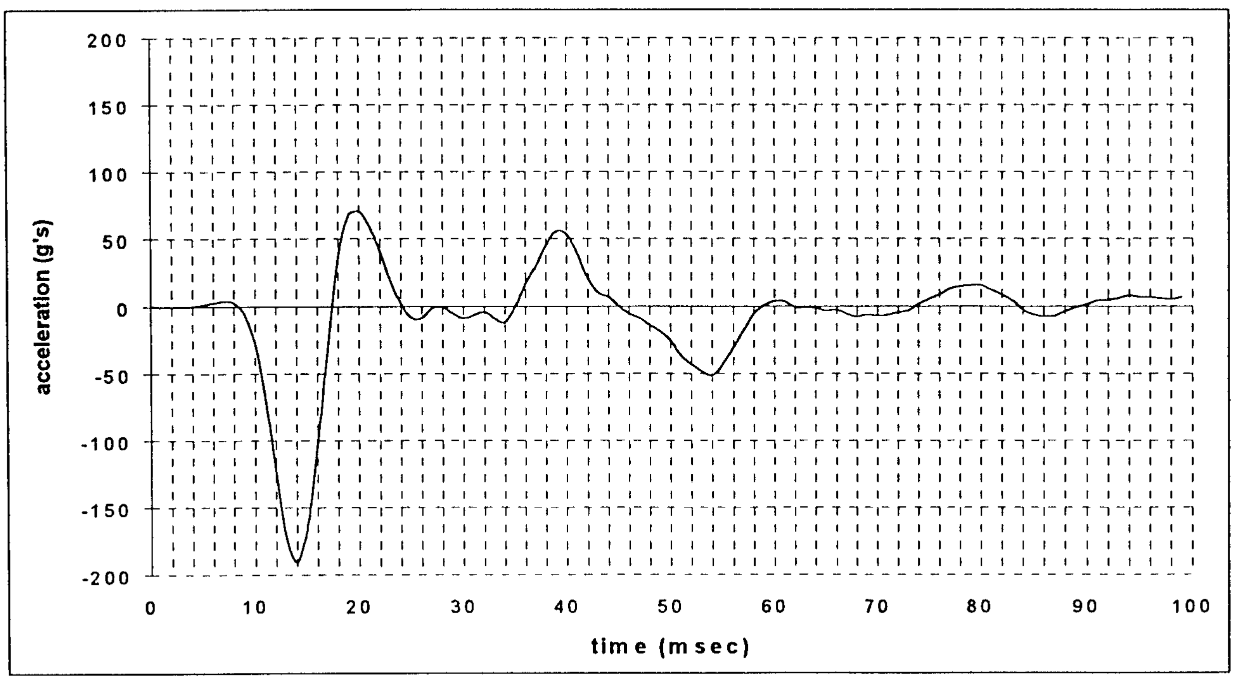


FIGURE A-14. FS 410 FLOOR, RIGHT SEAT TRACK VERTICAL ACCELERATION

WALL, SEAT TRACK DATA

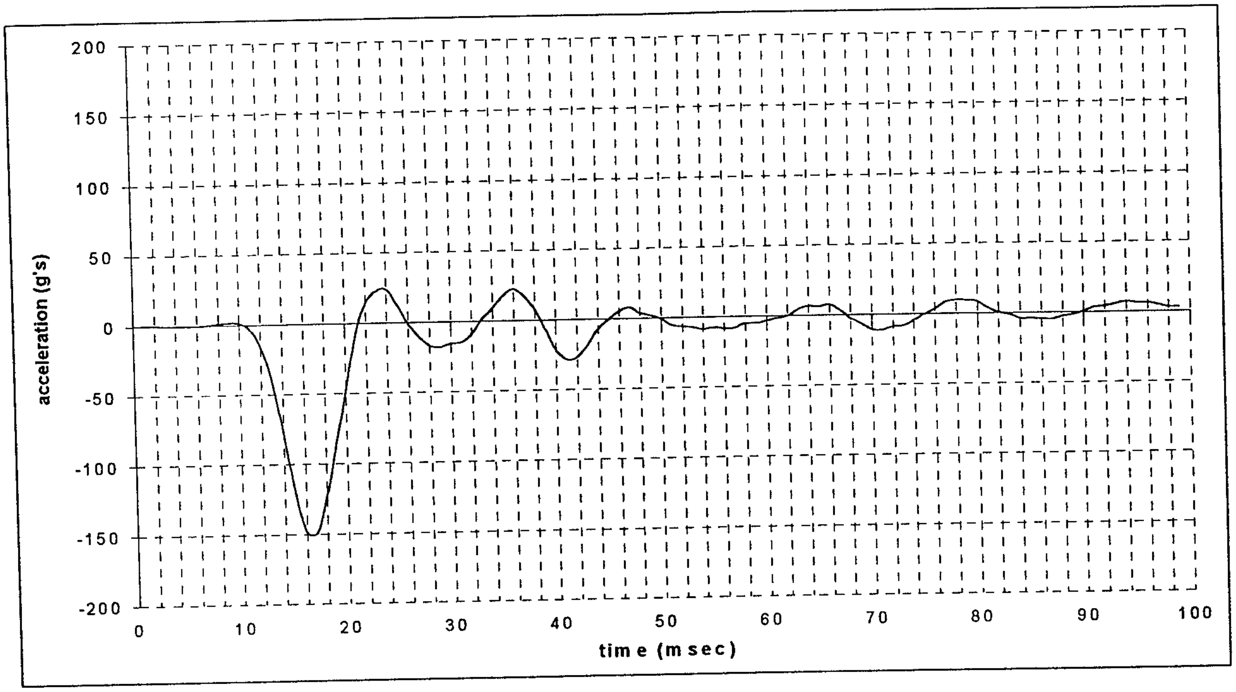


FIGURE A-15. FS 200 LEFT WALL, SEAT TRACK VERTICAL ACCELERATION

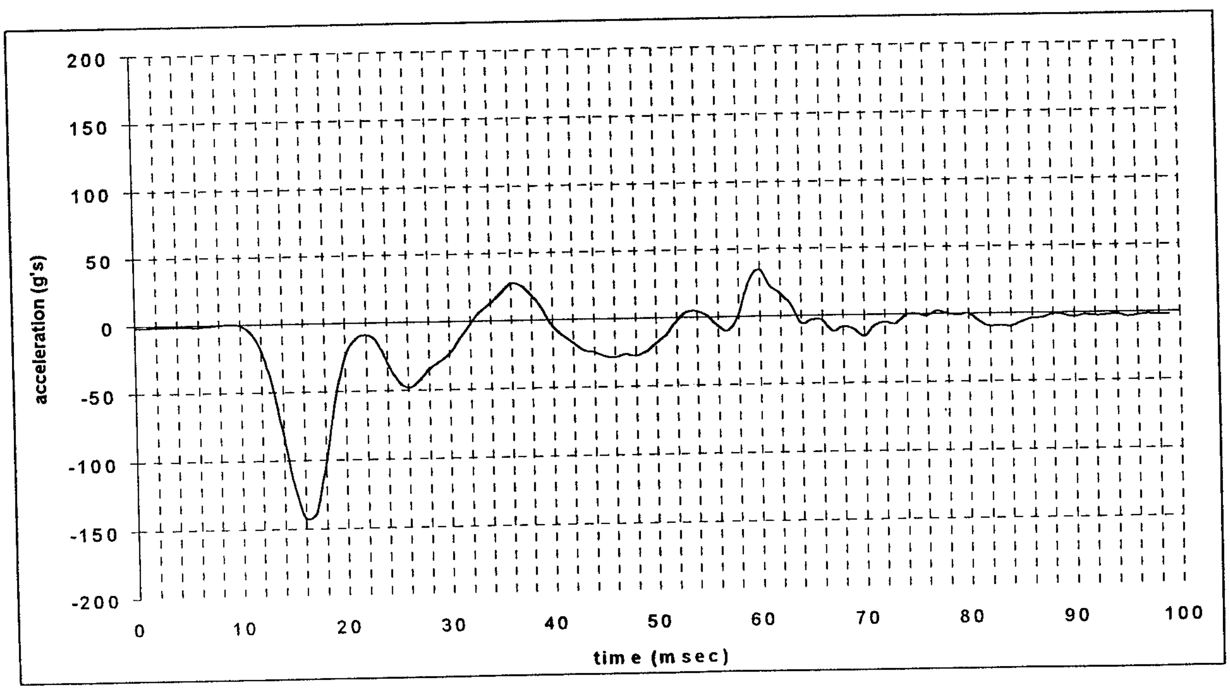


FIGURE A-16. FS 200 RIGHT WALL, SEAT TRACK VERTICAL ACCELERATION

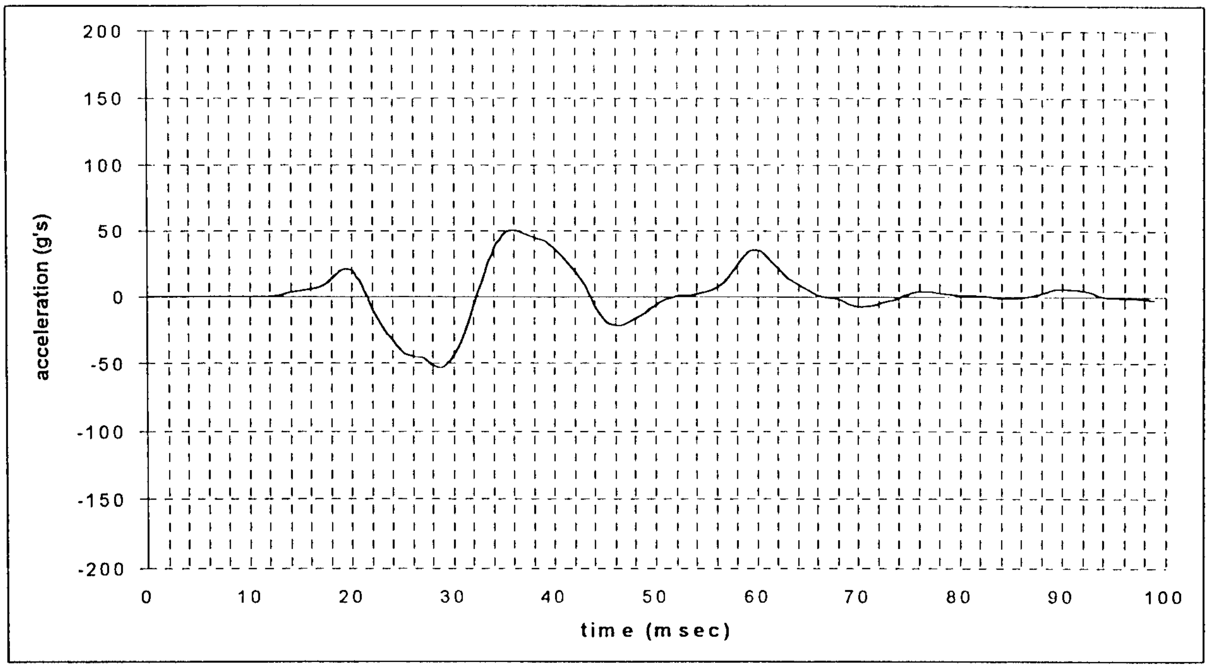


FIGURE A-17. FS 200 RIGHT WALL, SEAT TRACK LATERAL ACCELERATION

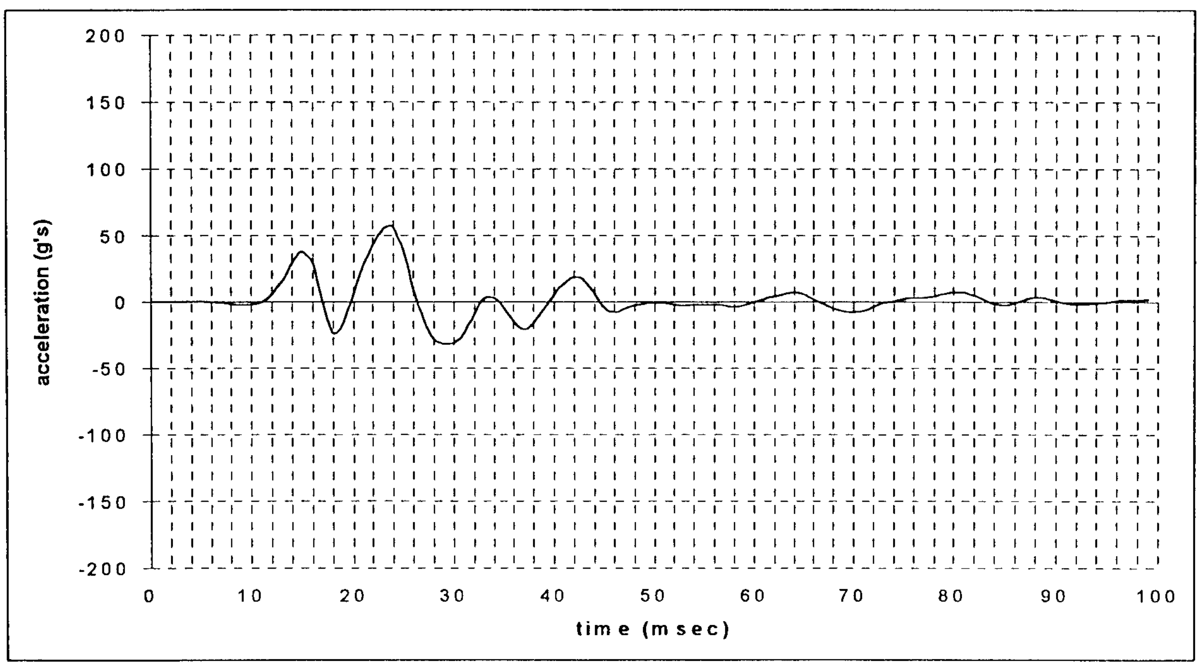


FIGURE A-18. FS 260 LEFT WALL, SEAT TRACK LATERAL ACCELERATION

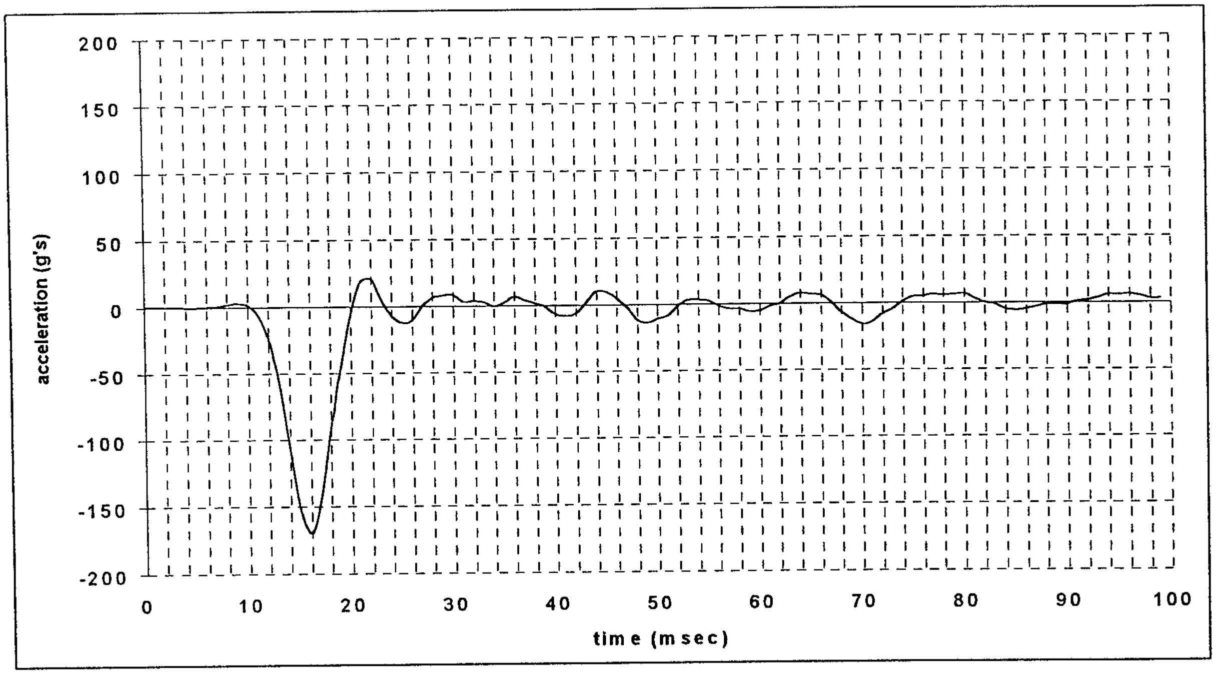


FIGURE A-19. FS 260 LEFT WALL, SEAT TRACK VERTICAL ACCELERATION

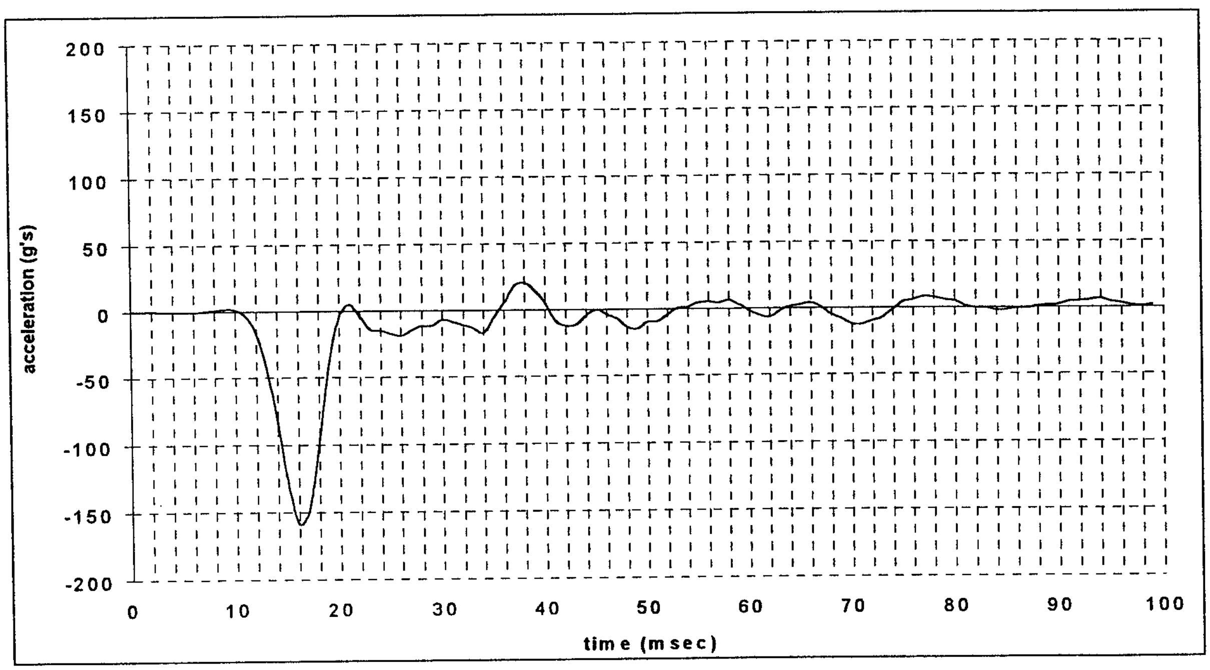


FIGURE A-20. FS 260 RIGHT WALL, SEAT TRACK VERTICAL ACCELERATION

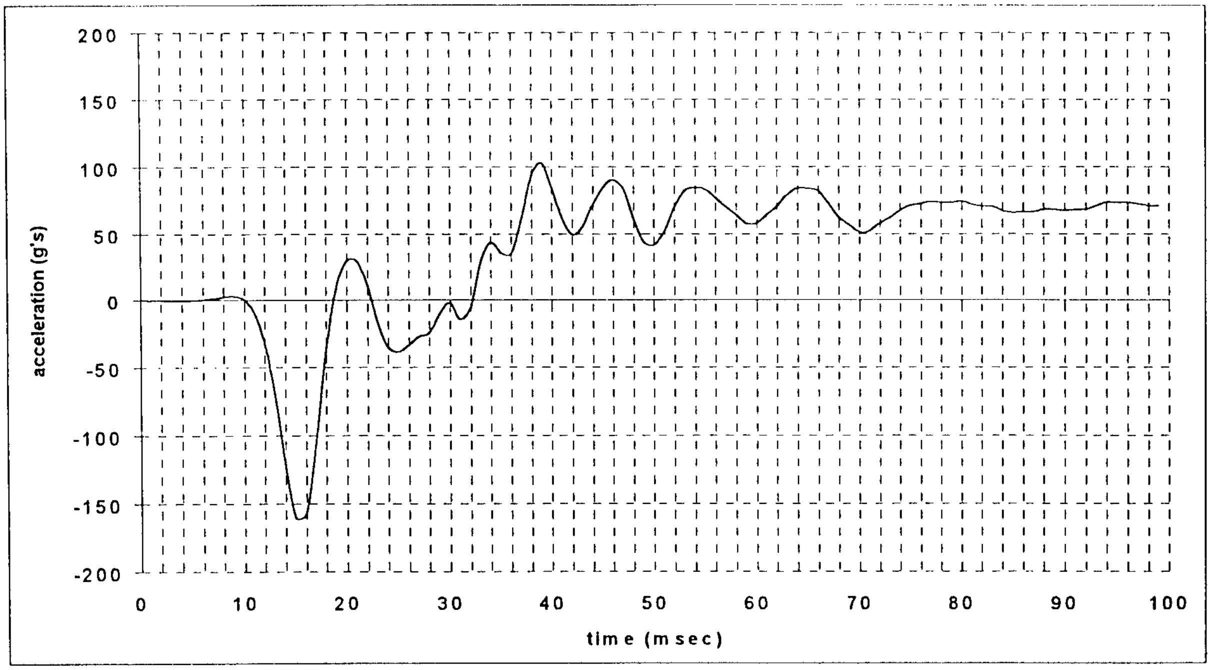


FIGURE A-21. FS 290 LEFT WALL, SEAT TRACK VERTICAL ACCELERATION

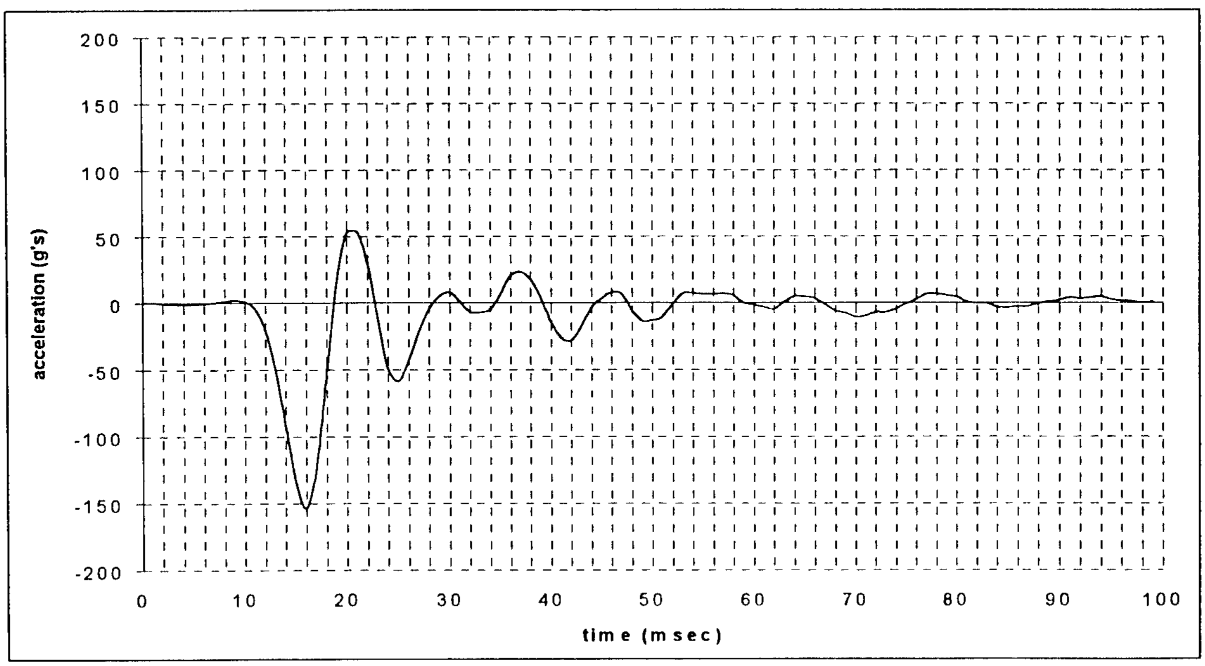


FIGURE A-22. FS 290 RIGHT WALL, SEAT TRACK VERTICAL ACCELERATION

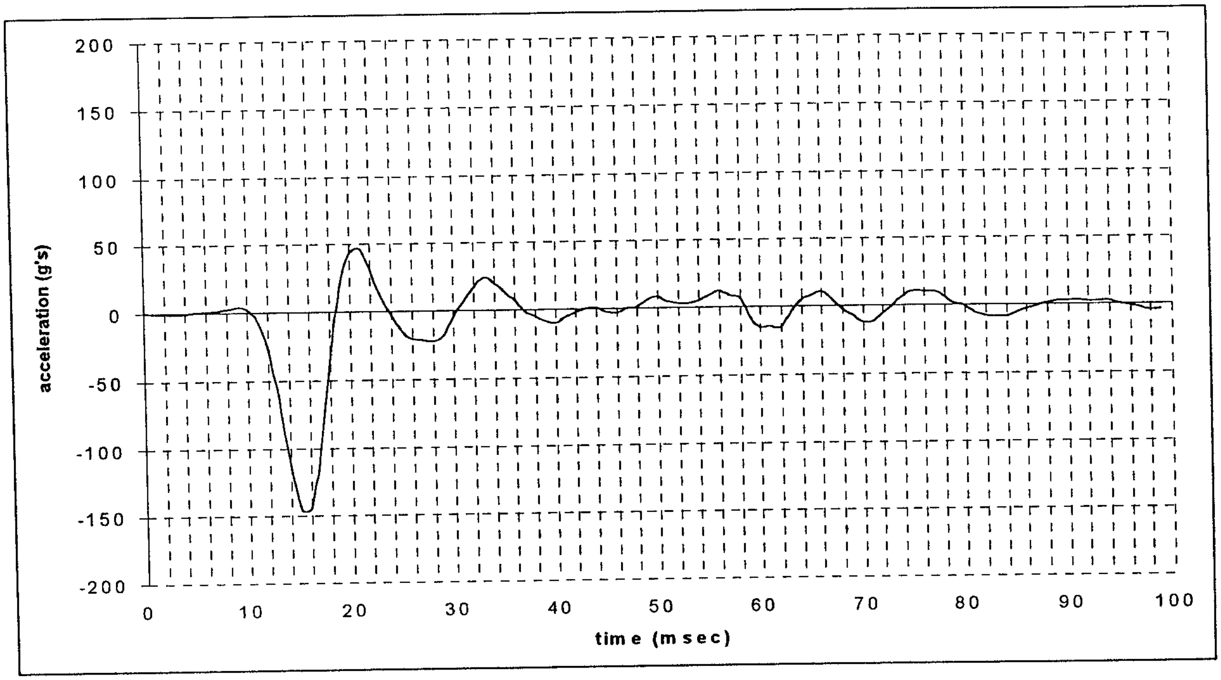


FIGURE A-23. FS 410 LEFT WALL, SEAT TRACK VERTICAL ACCELERATION

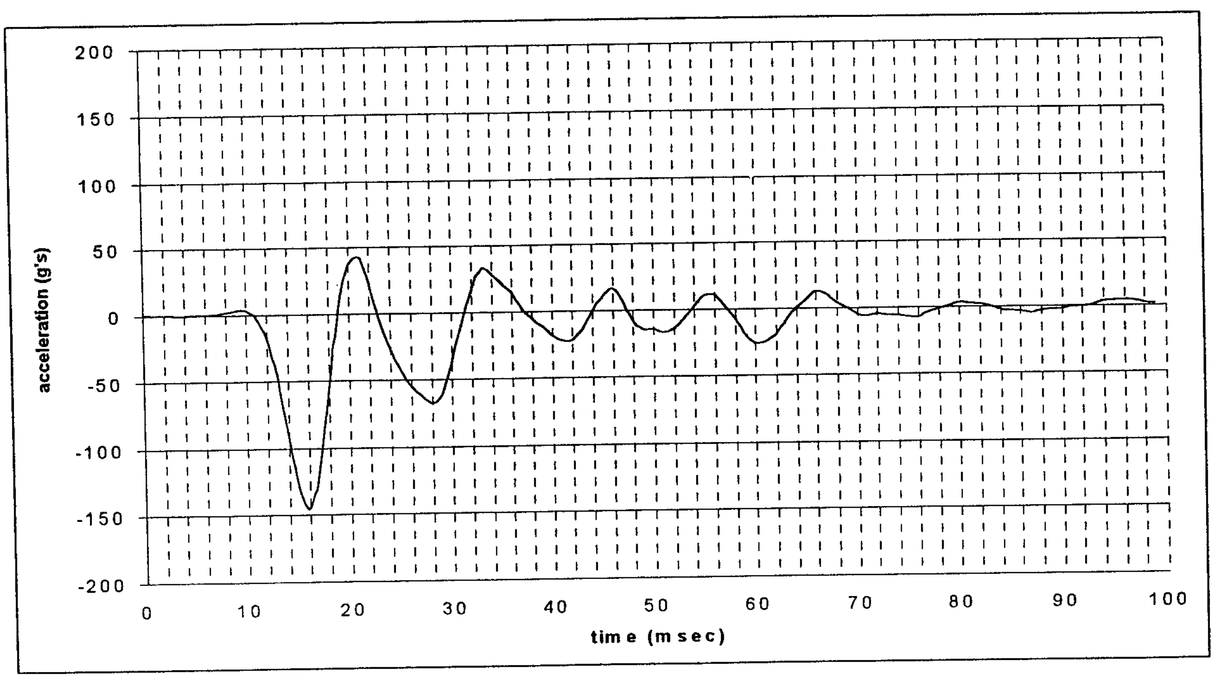


FIGURE A-24. FS 410 RIGHT WALL, SEAT TRACK VERTICAL ACCELERATION

WALL DATA

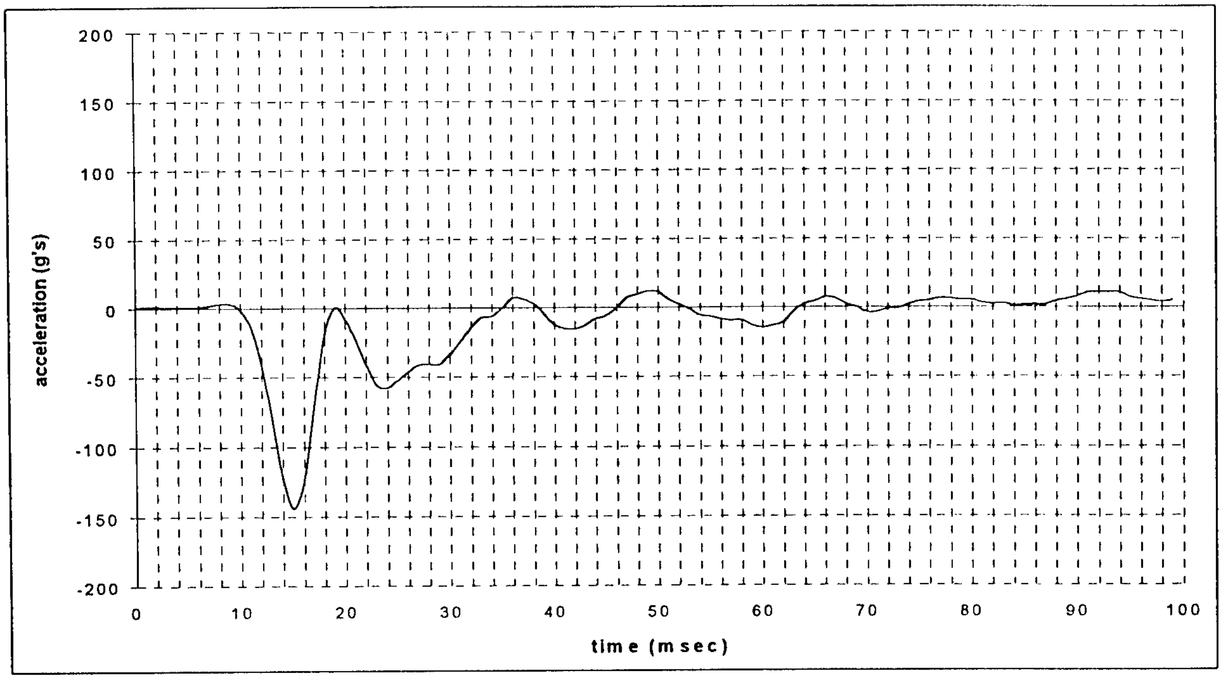


FIGURE A-25. FS 129 WALL, LEFT VERTICAL ACCELERATION

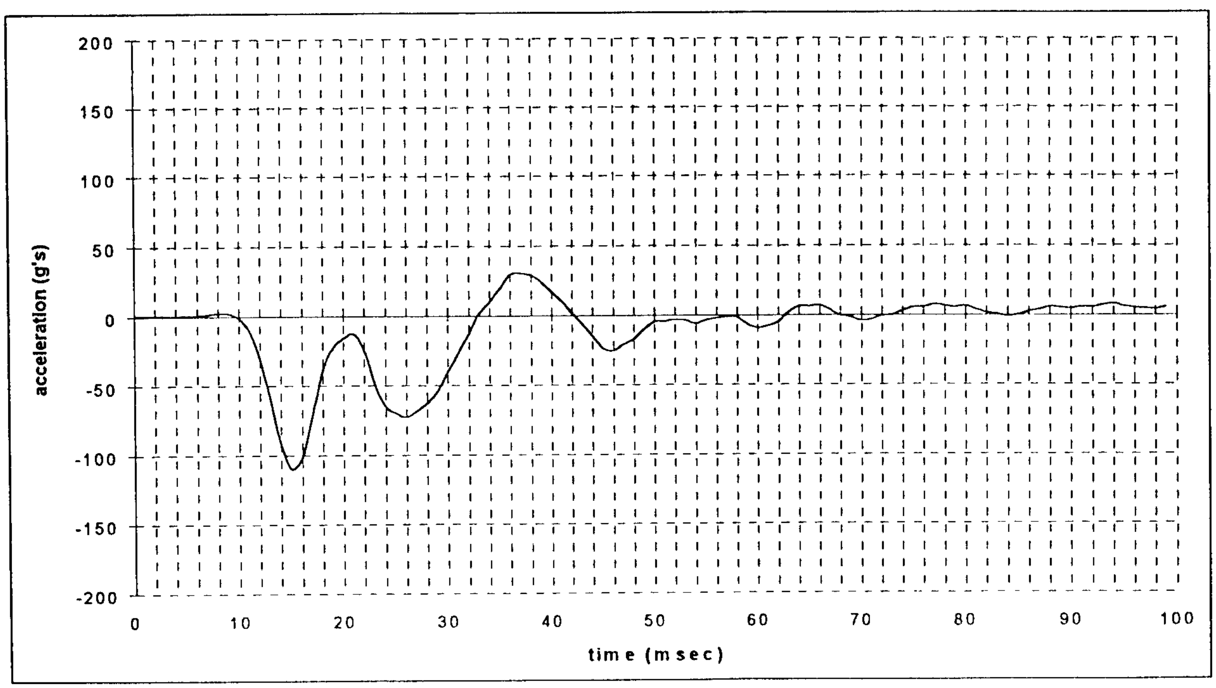


FIGURE A-26. FS 129 WALL, RIGHT VERTICAL ACCELERATION

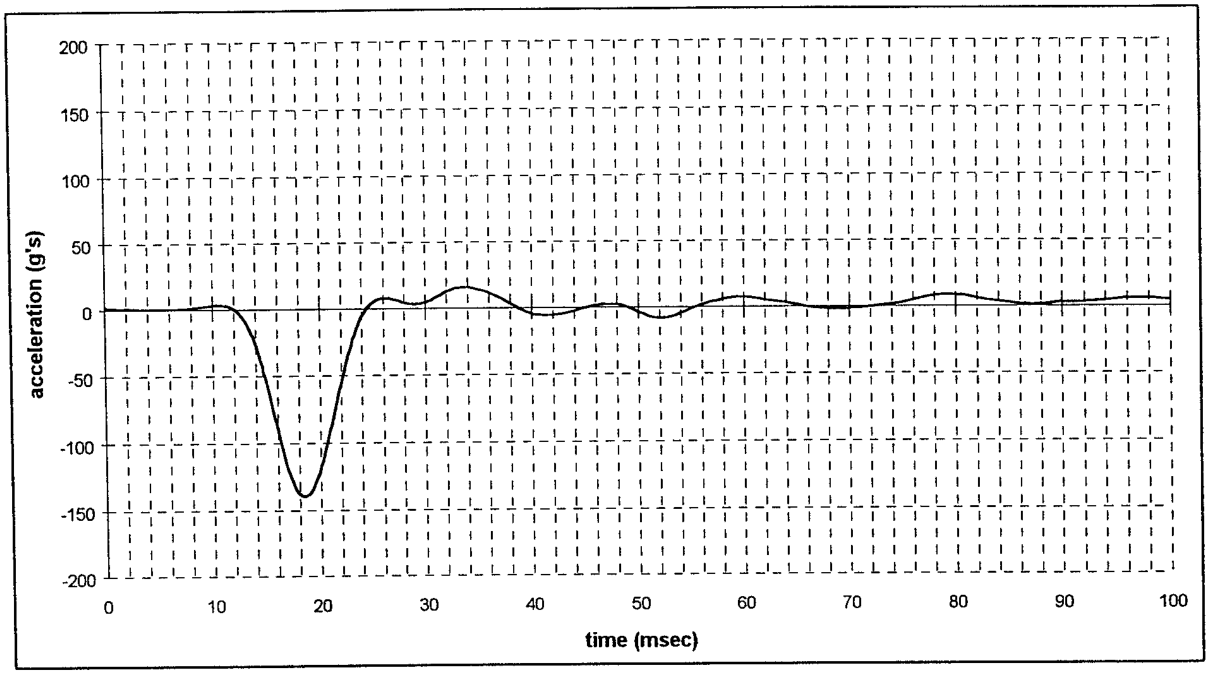


FIGURE A-27. FS 200 WALL, LEFT VERTICAL ACCELERATION

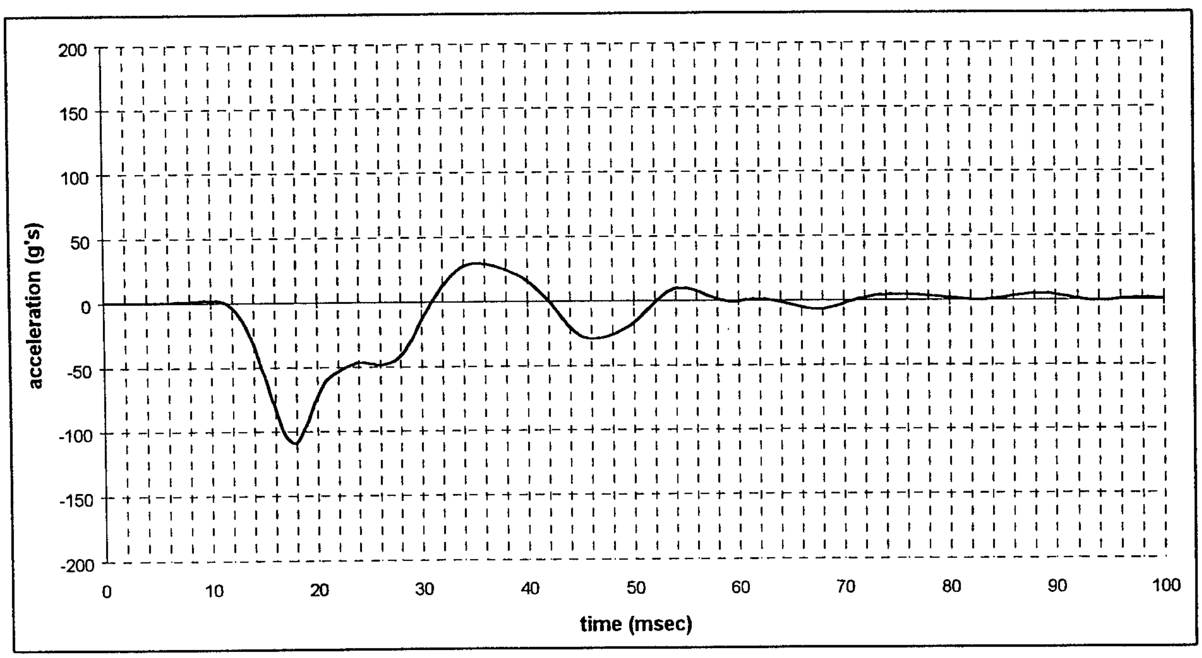


FIGURE A-28. FS 200 WALL, RIGHT VERTICAL ACCELERATION

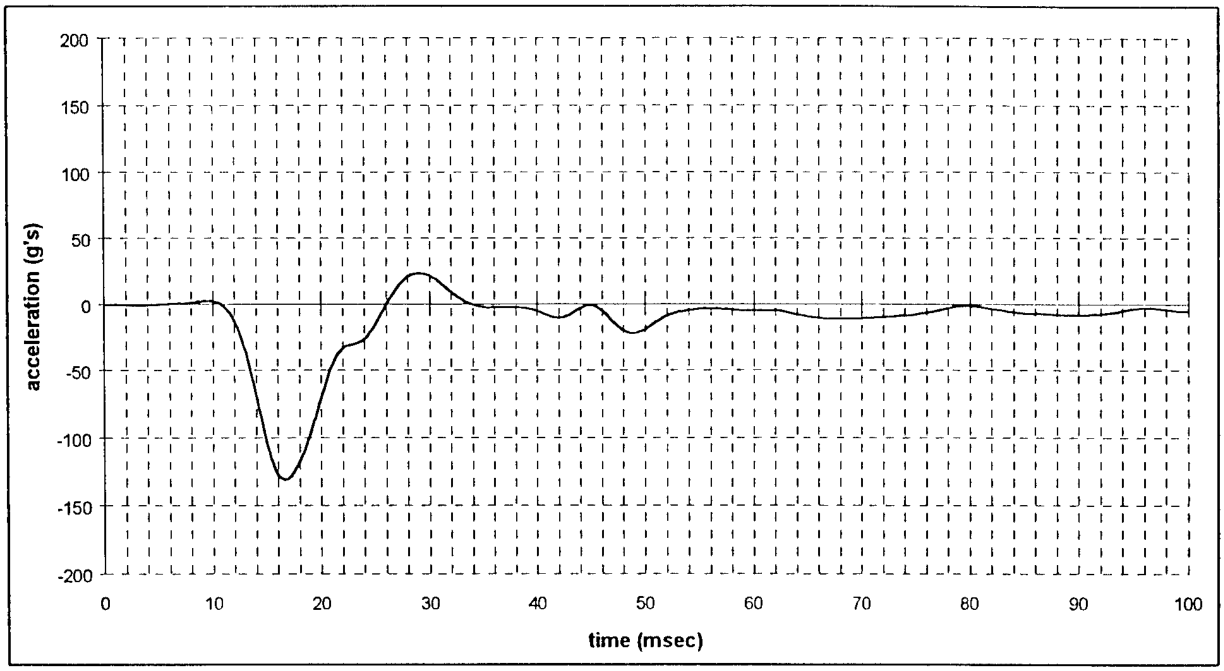


FIGURE A-29. FS 260 WALL, LEFT VERTICAL ACCELERATION

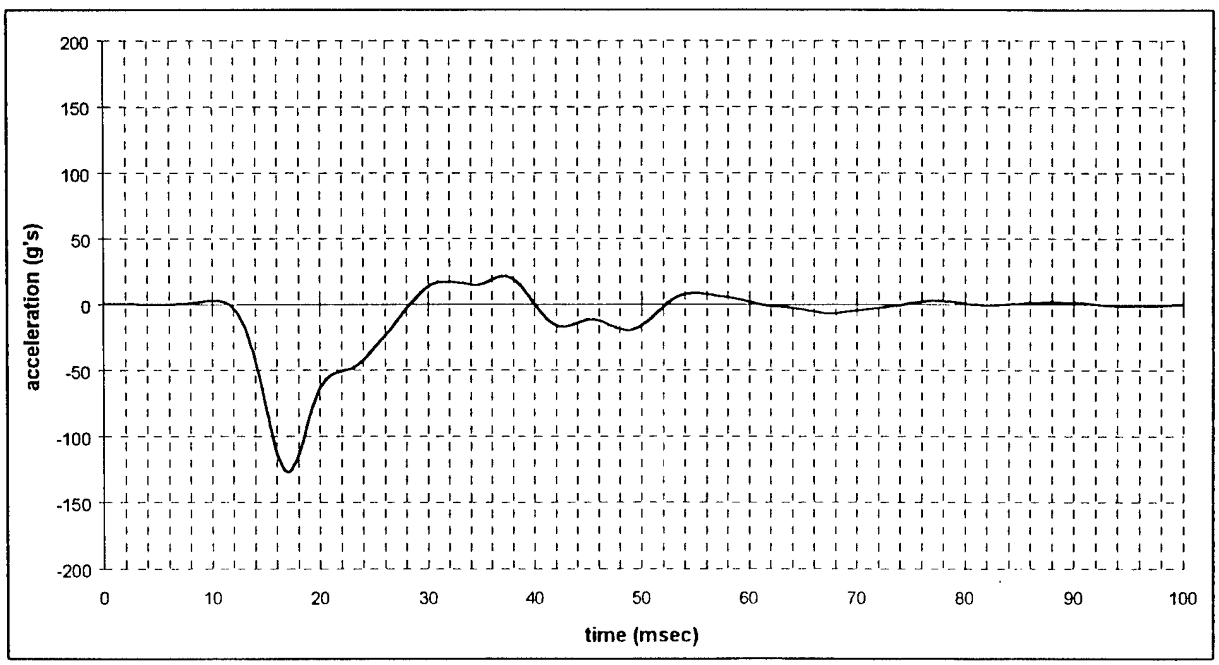


FIGURE A-30. FS 260 WALL, RIGHT VERTICAL ACCELERATION

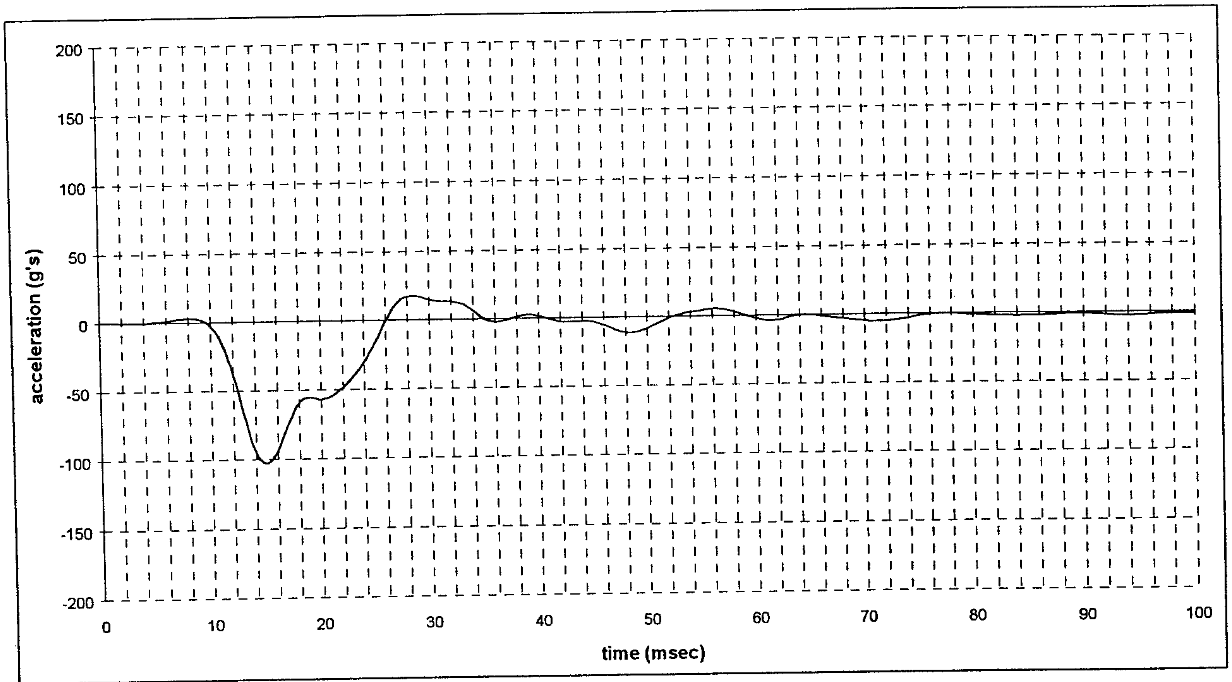


FIGURE A-31. FS 320 WALL, LEFT VERTICAL ACCELERATION

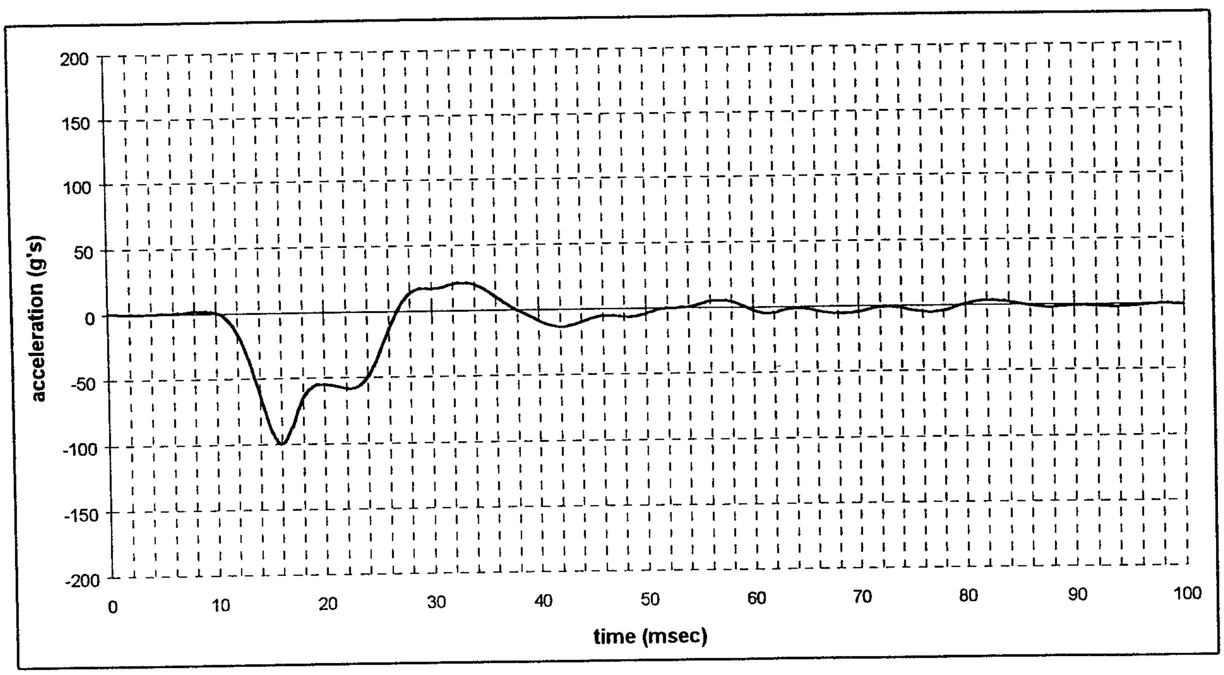


FIGURE A-32. FS 320 WALL, RIGHT VERTICAL ACCELERATION

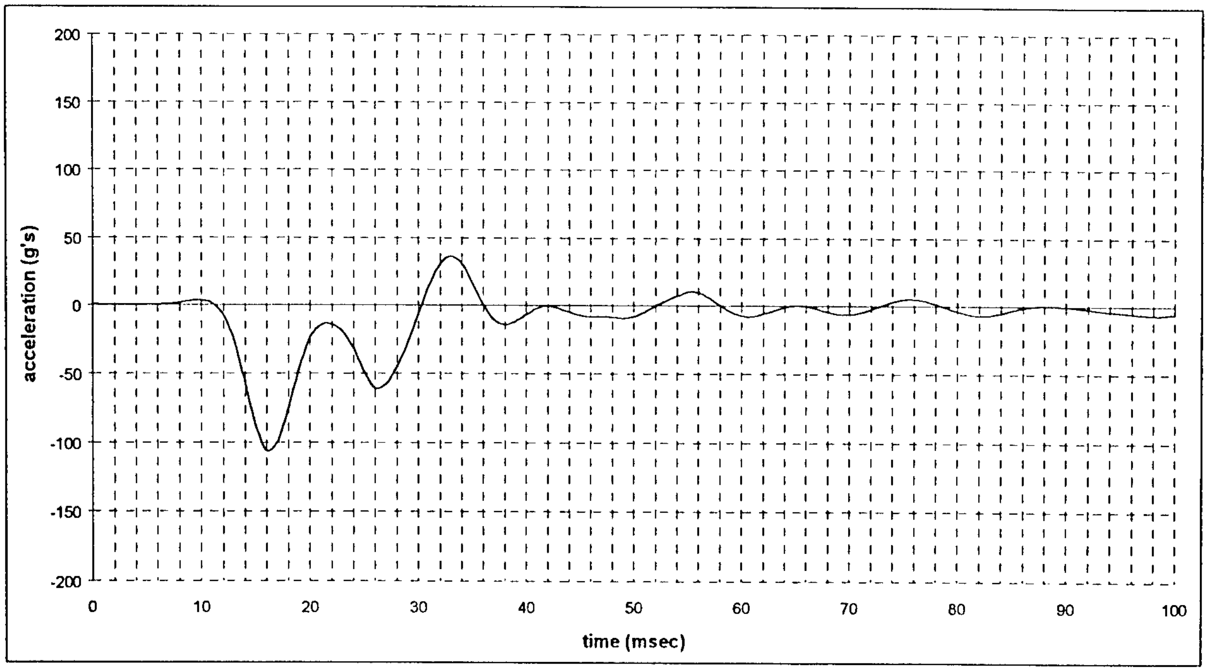


FIGURE A-33. FS 410 WALL, LEFT VERTICAL ACCELERATION

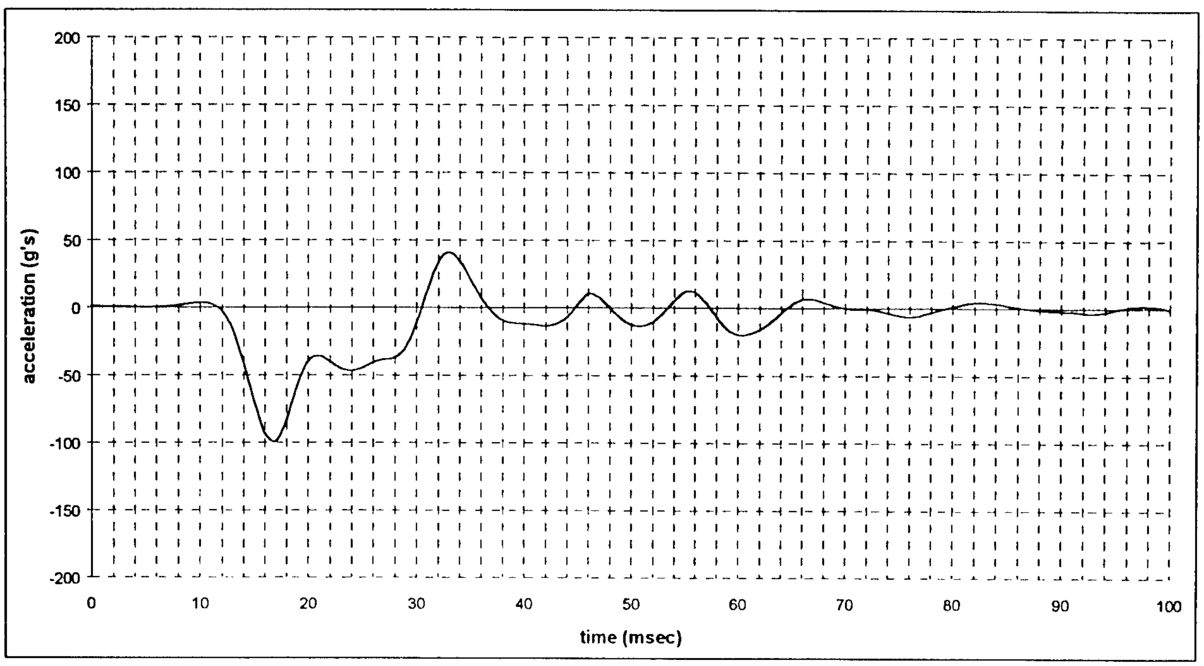


FIGURE A-34. FS 410 WALL, RIGHT VERTICAL ACCELERATION

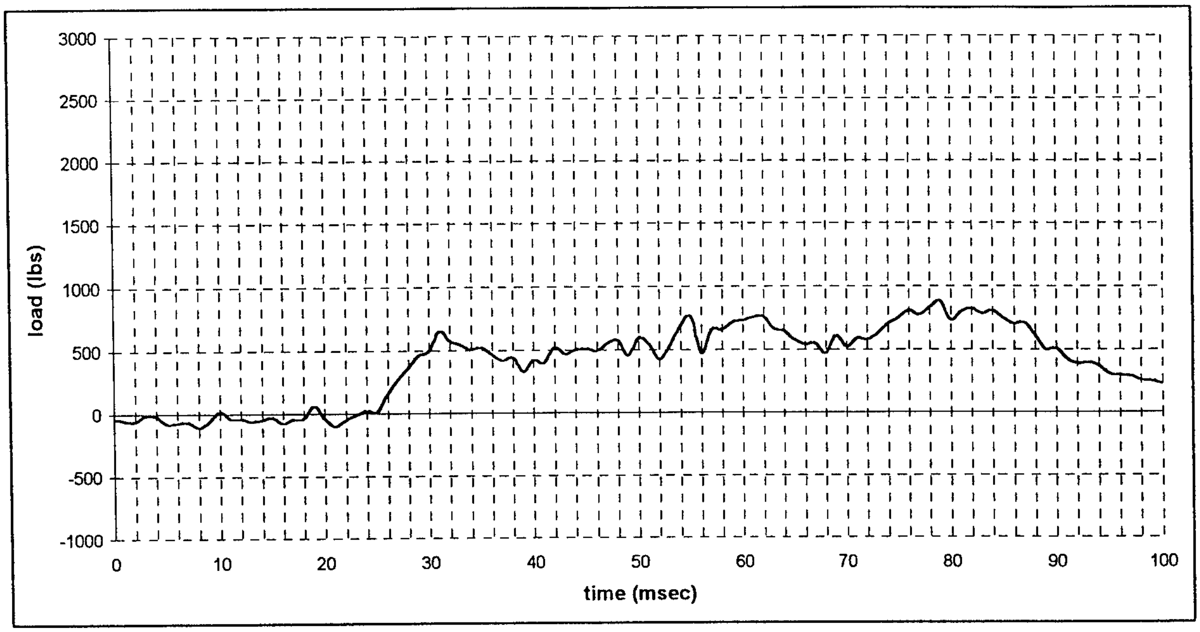


FIGURE A-35. FS 200 RIGHT WSU SEAT DUMMY PELVIS LOAD

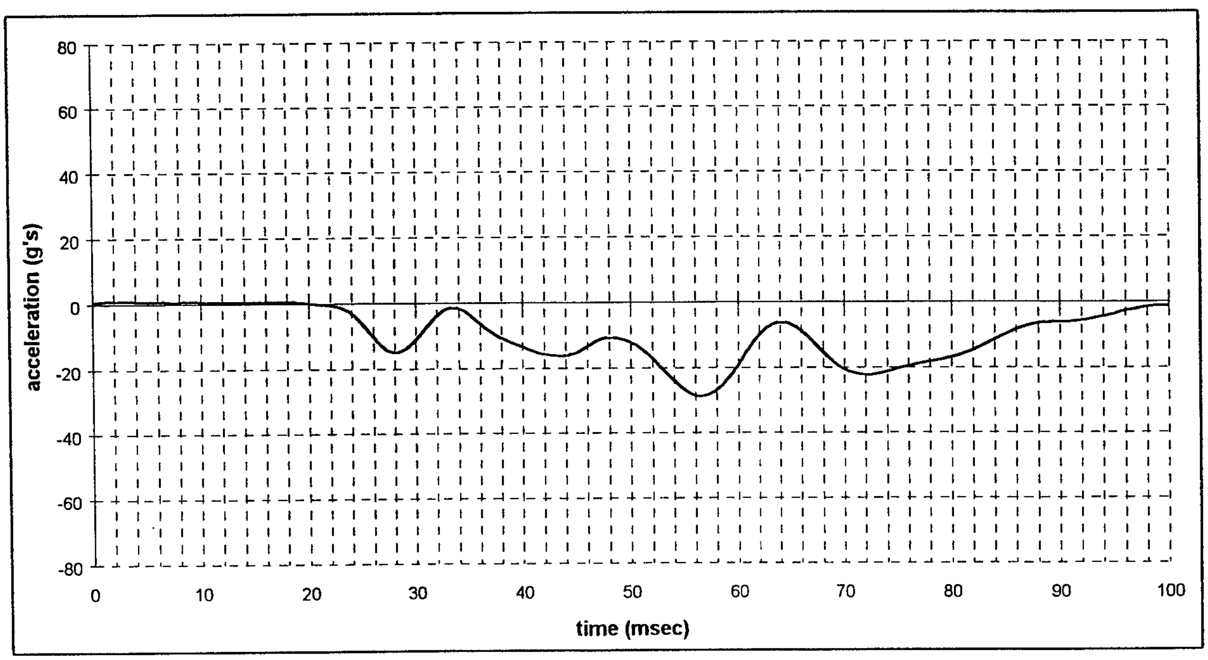


FIGURE A-36. FS 200 RIGHT WSU SEAT DUMMY PELVIS ACCELERATION

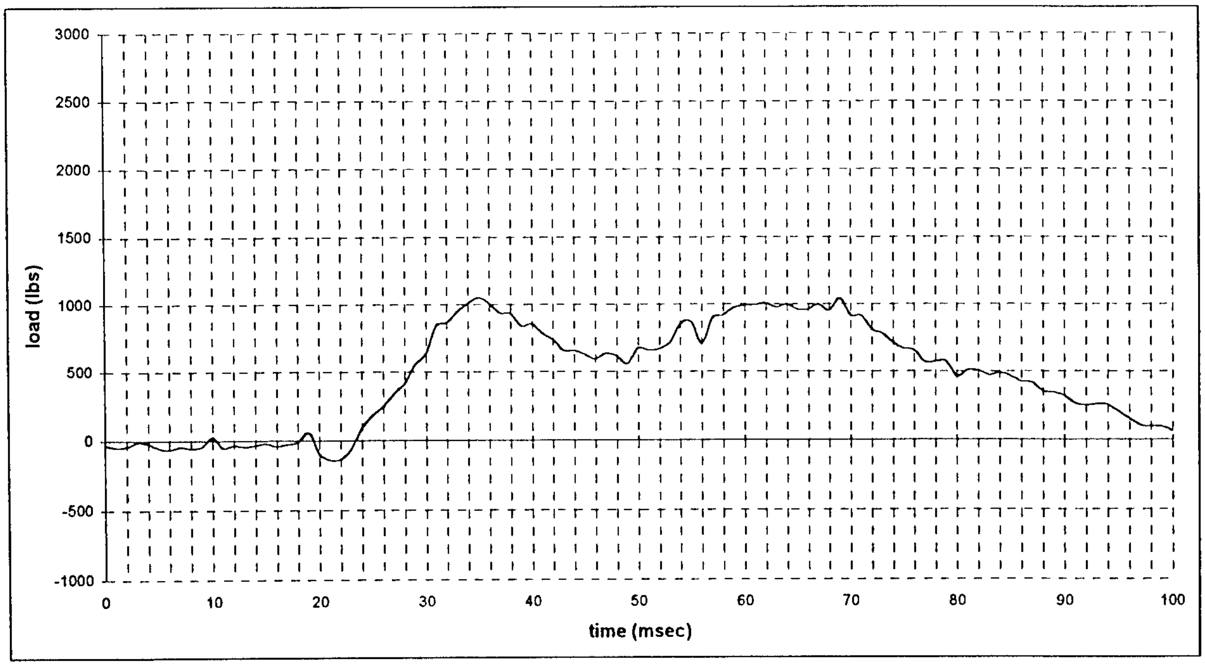


FIGURE A-37. FS 260 LEFT WSU SEAT DUMMY PELVIS LOAD

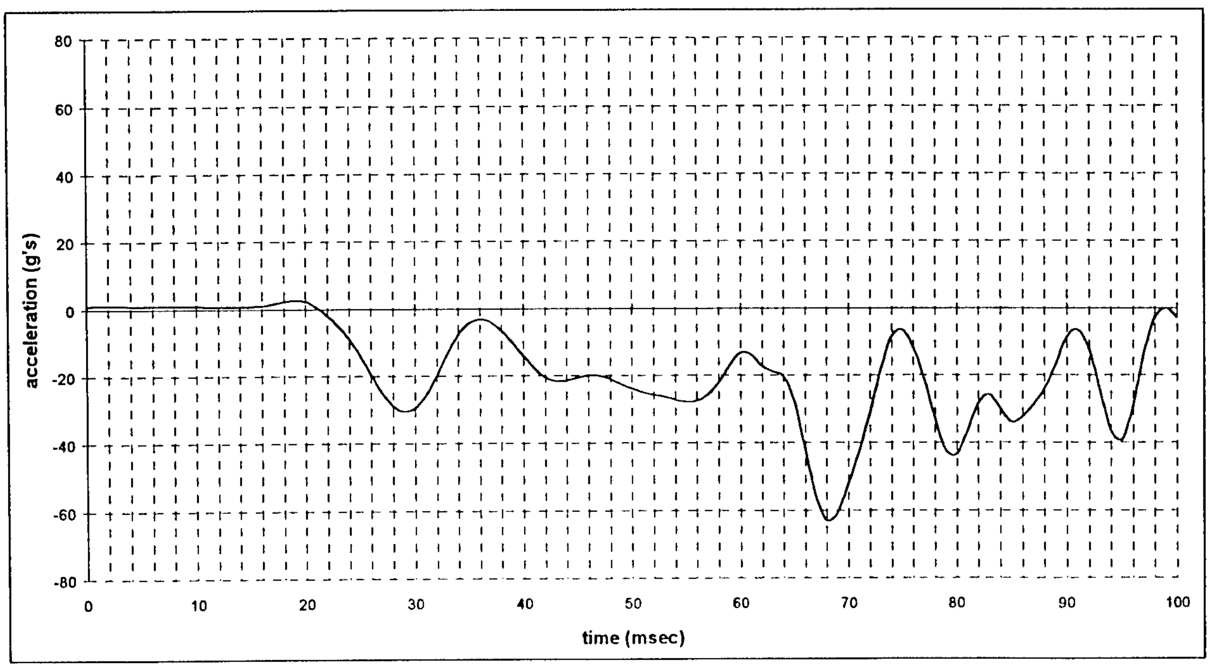


FIGURE A-38. FS 260 LEFT WSU SEAT DUMMY PELVIS ACCELERATION

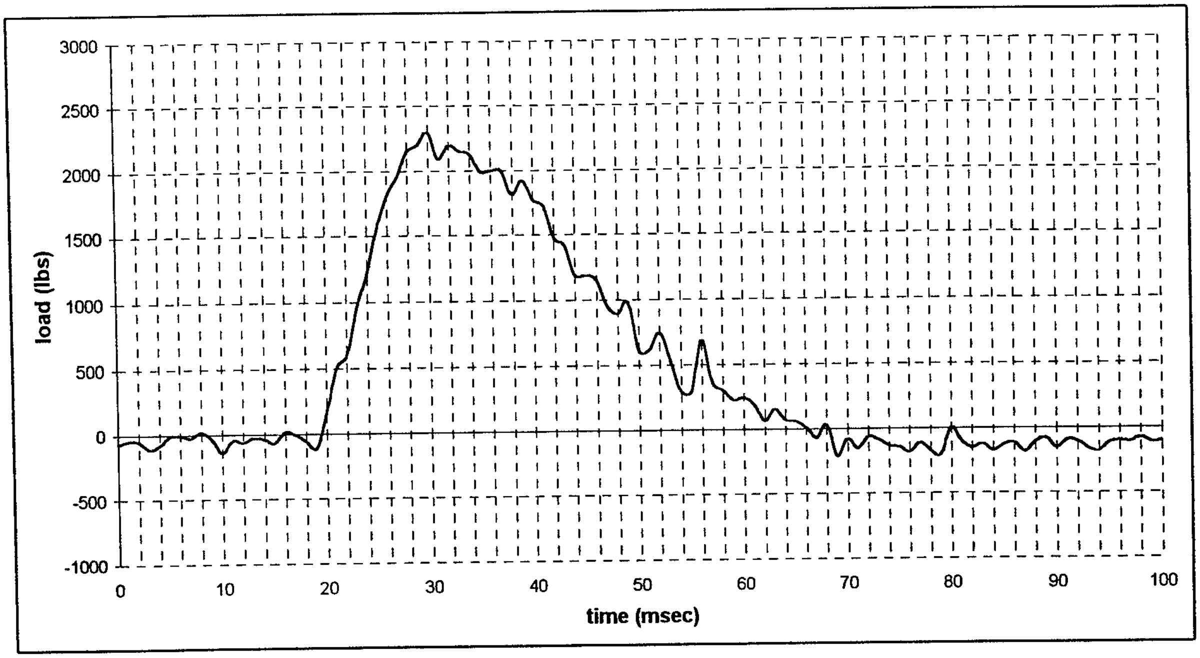


FIGURE A-39. FS 290 RIGHT PTC SEAT DUMMY PELVIS LOAD

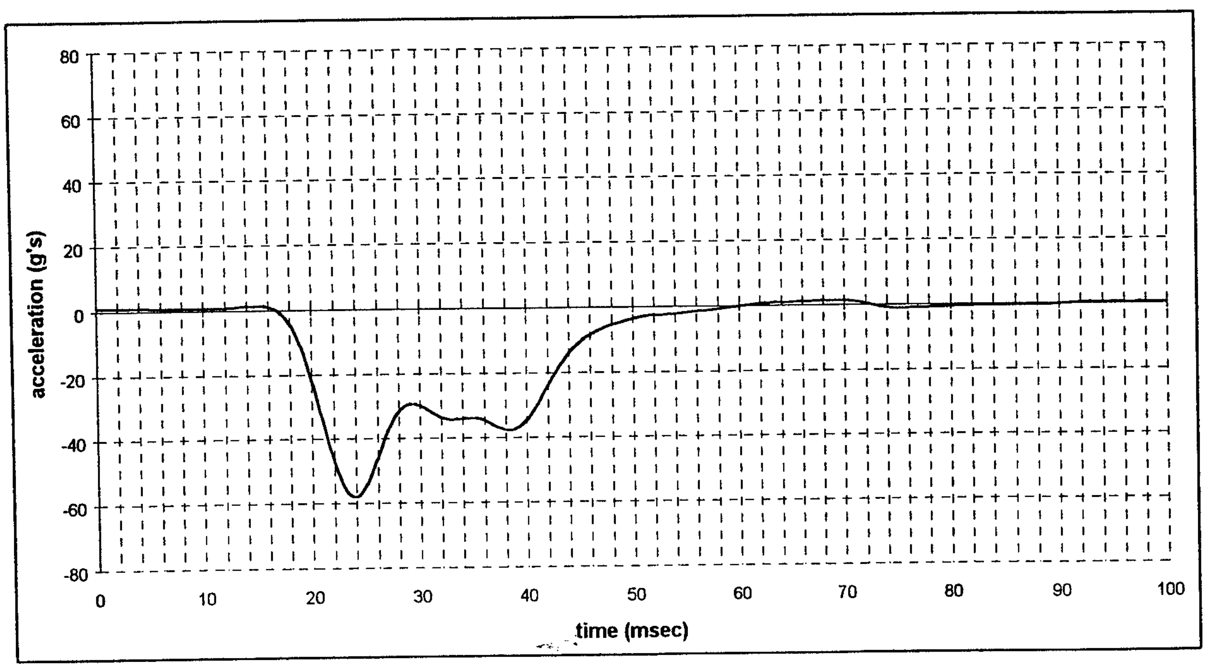


FIGURE A-40. FS 290 RIGHT PTC SEAT DUMMY PELVIS ACCELERATION

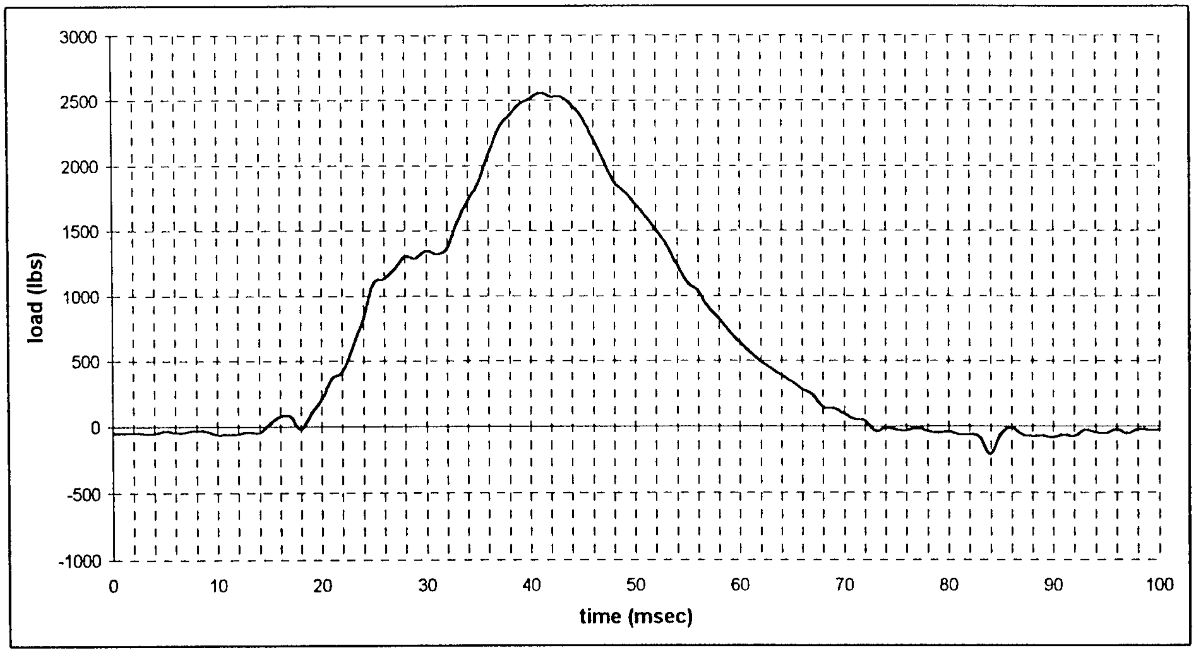


FIGURE A-41. FS 320 CENTER CAMI SEAT DUMMY PELVIS LOAD

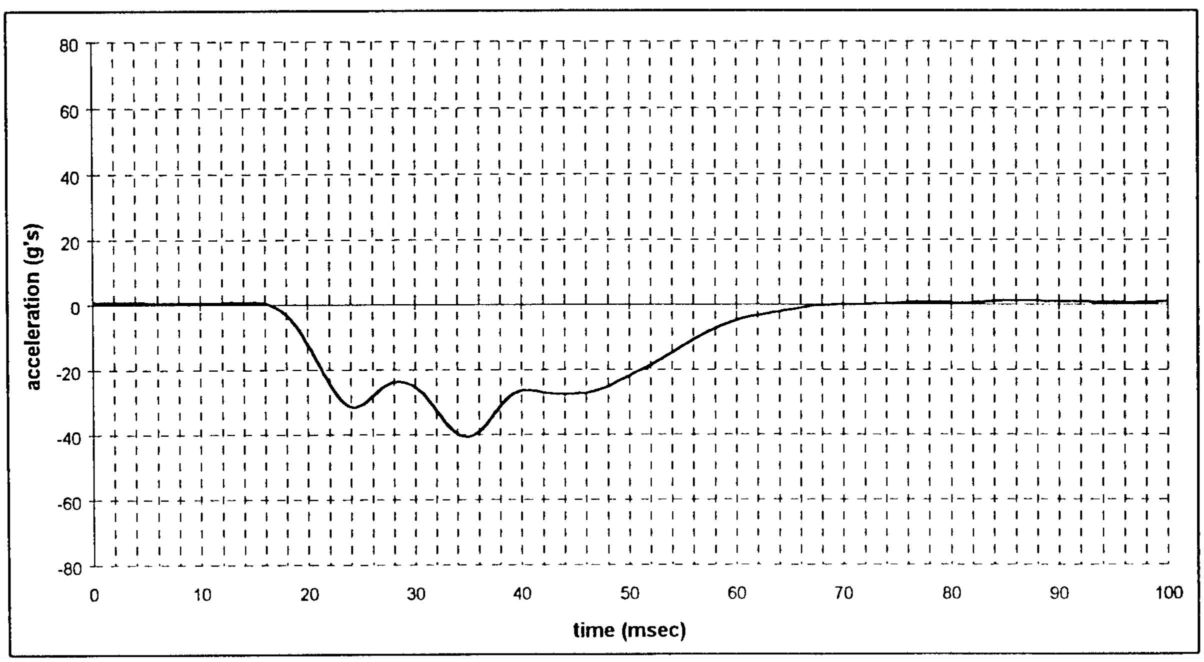


FIGURE A-42. FS 320 CENTER CAMI SEAT DUMMY PELVIS ACCELERATION

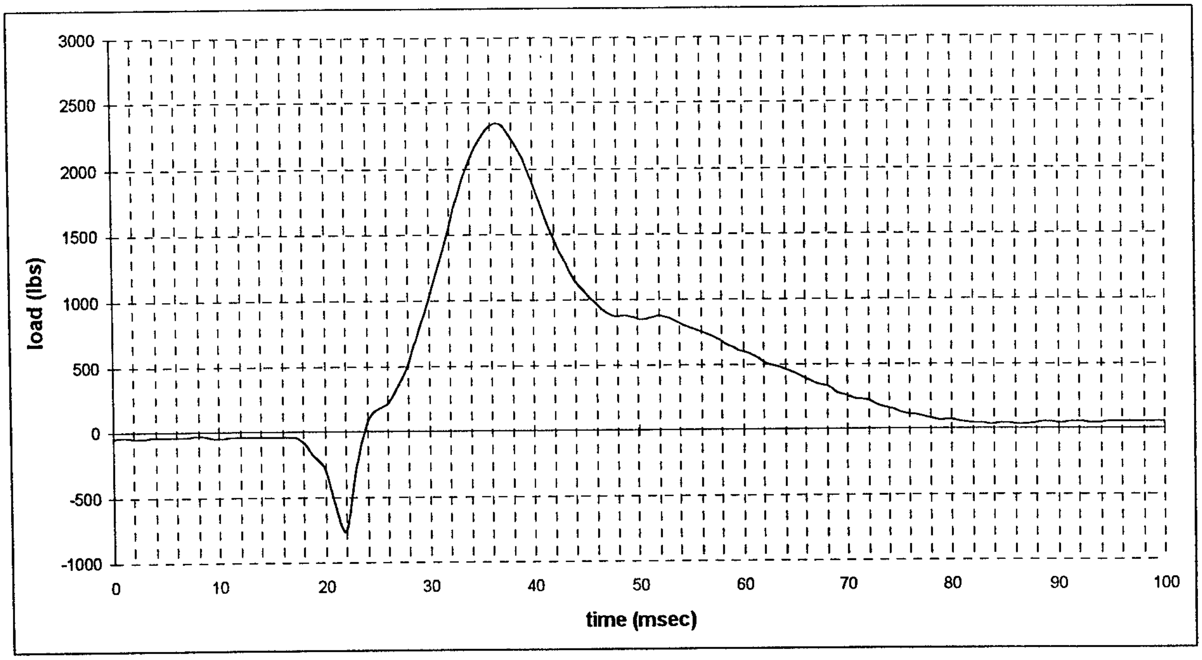


FIGURE A-43. FS 350 CENTER BEECH SEAT DUMMY PELVIS LOAD

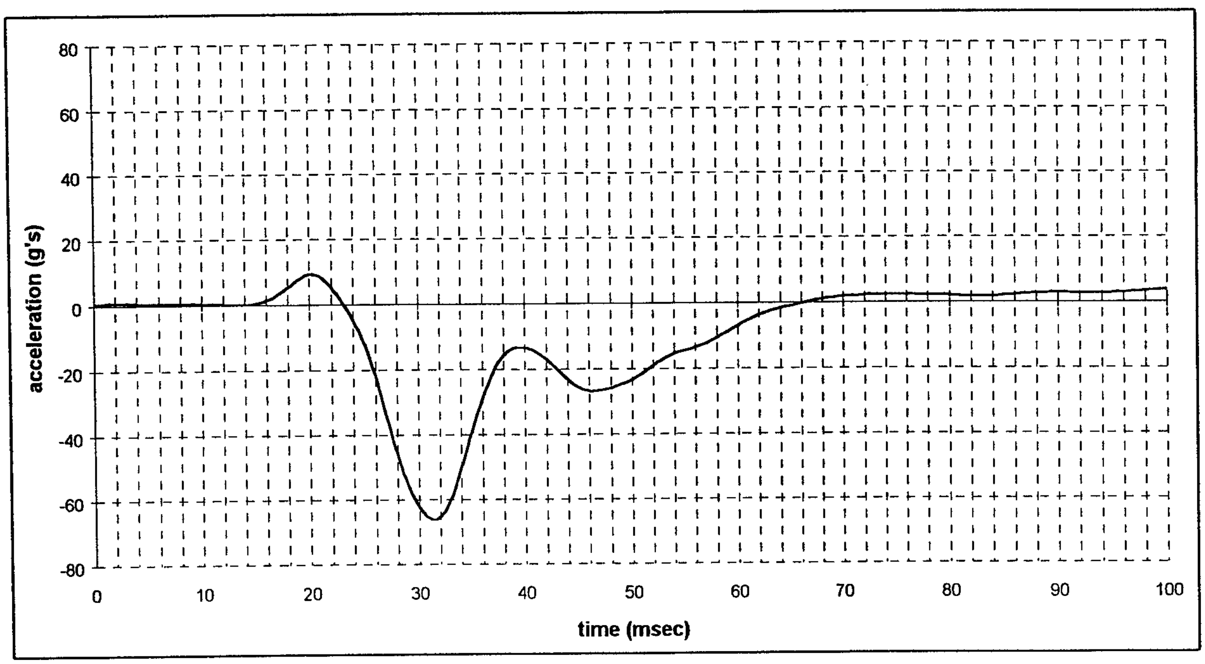


FIGURE A-44. FS 350 CENTER BEECH SEAT DUMMY PELVIS ACCELERATION

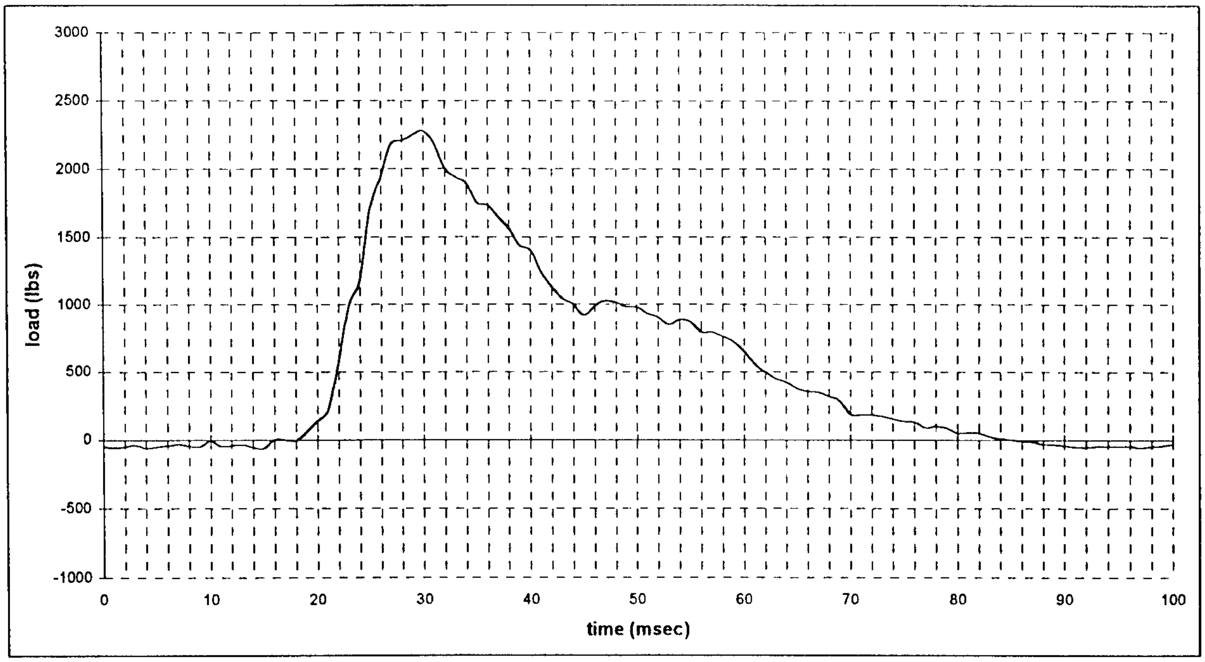


FIGURE A-45. FS 380 LEFT PTC SEAT DUMMY PELVIS LOAD

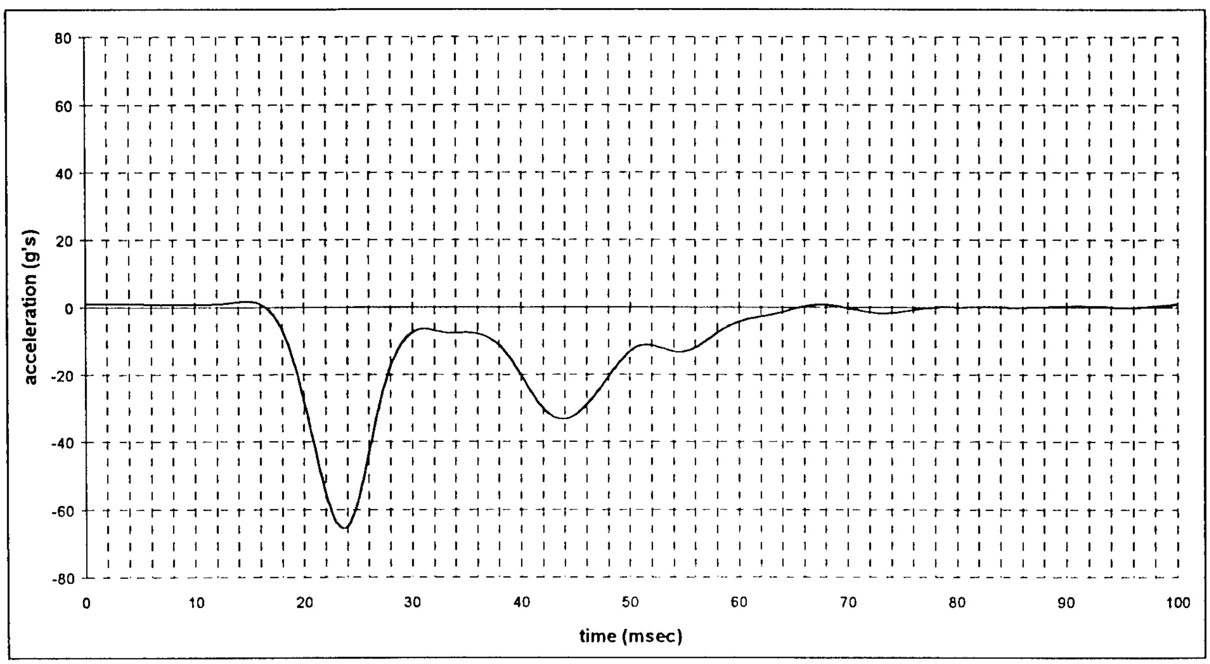


FIGURE A-46. FS 380 LEFT PTC SEAT DUMMY PELVIS ACCELERATION

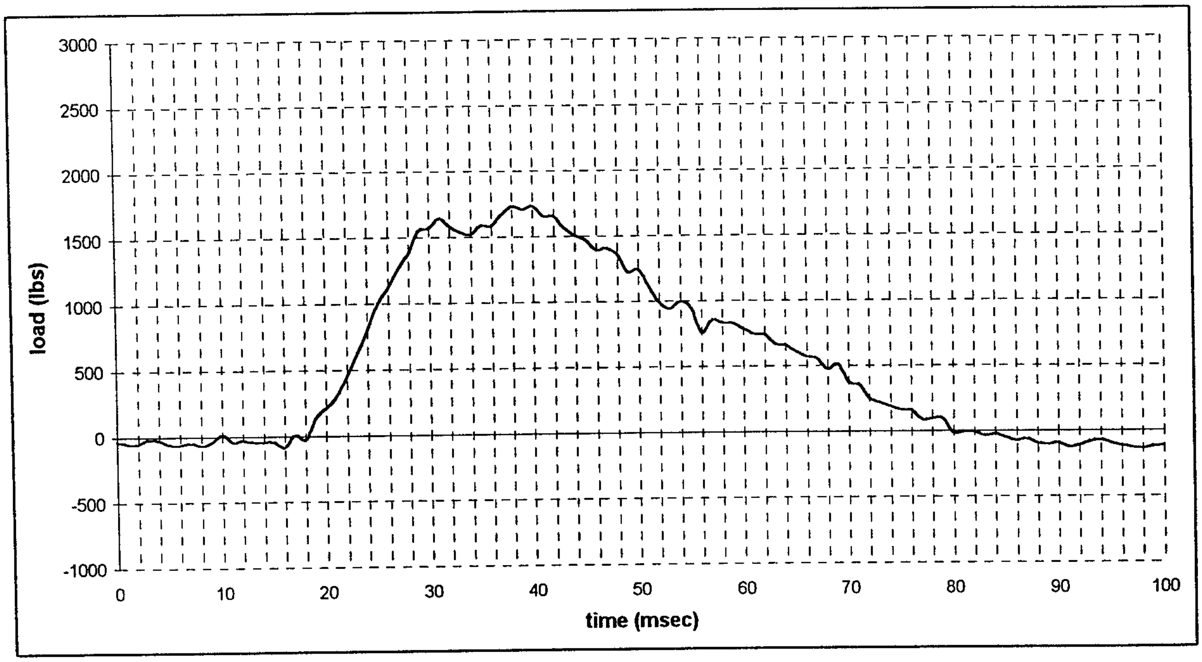


FIGURE A-47. FS 380 RIGHT BEECH SEAT DUMMY PELVIS LOAD

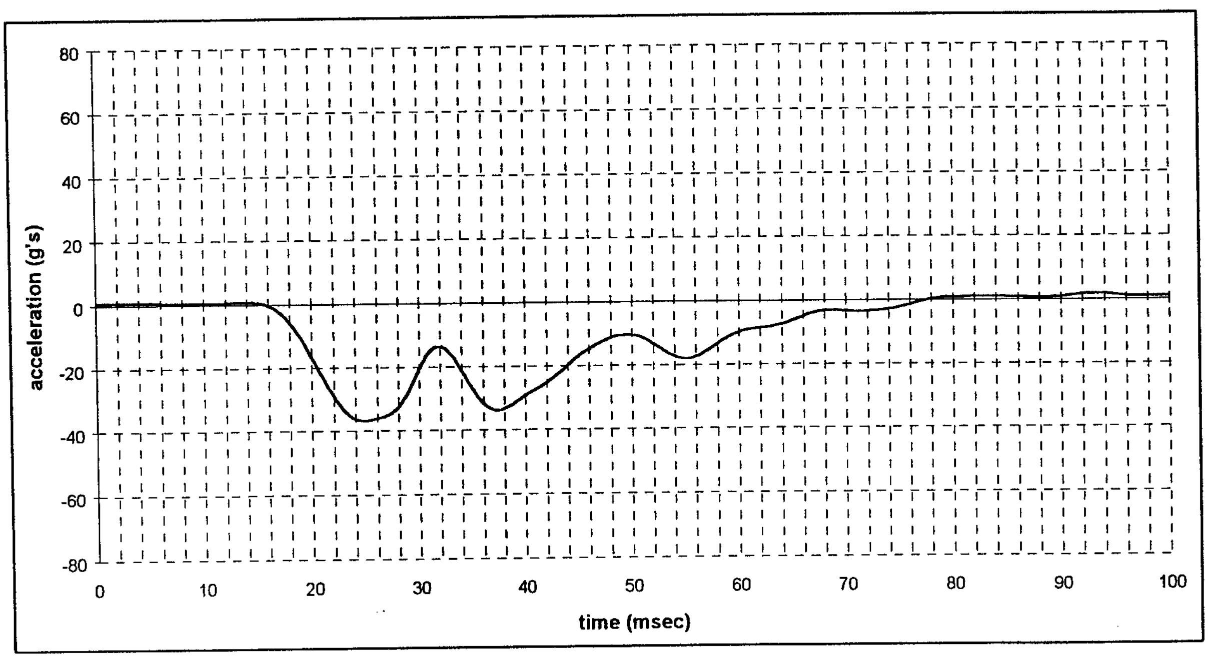


FIGURE A-48. FS 380 RIGHT BEECH SEAT DUMMY PELVIS ACCELERATION

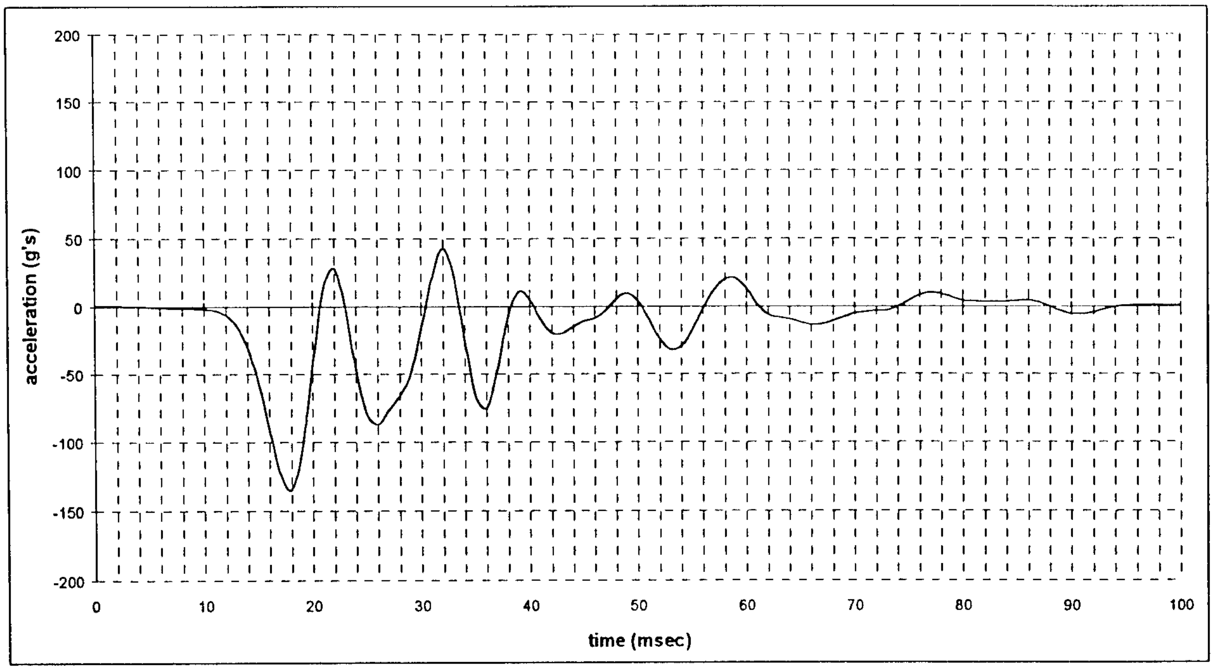


FIGURE A-49. FS 260 RIGHT BEECH SEAT PAN VERTICAL ACCELERATION

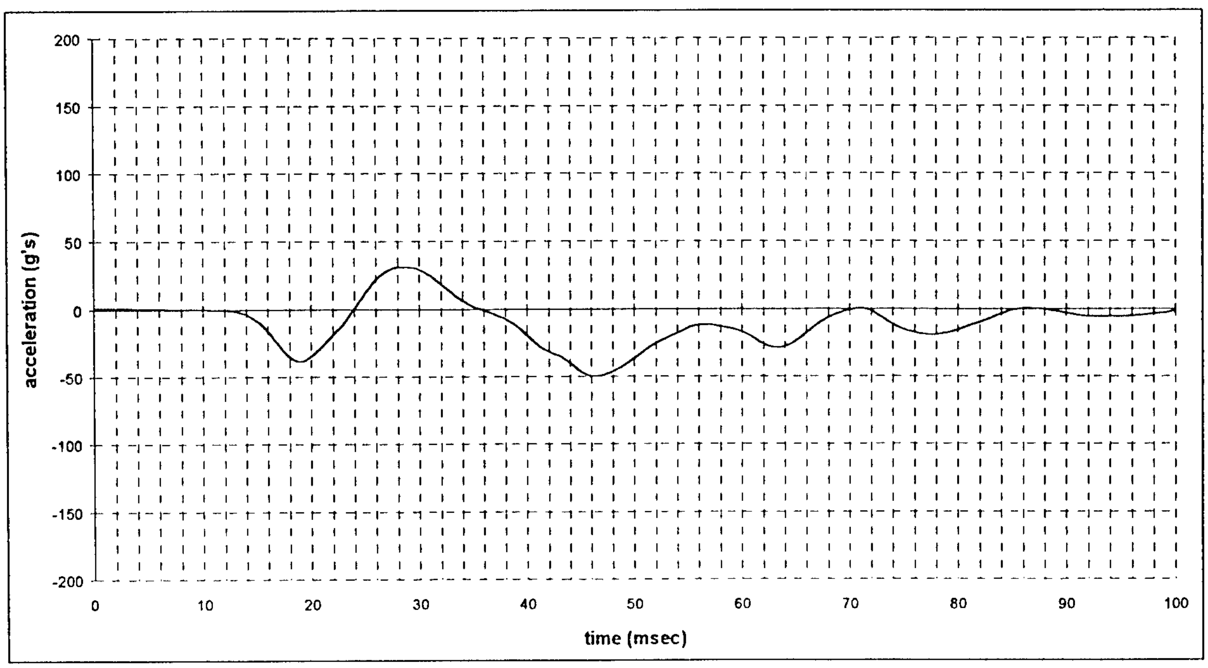


FIGURE A-50. FS 260 LEFT WSU SEAT PAN VERTICAL ACCELERATION

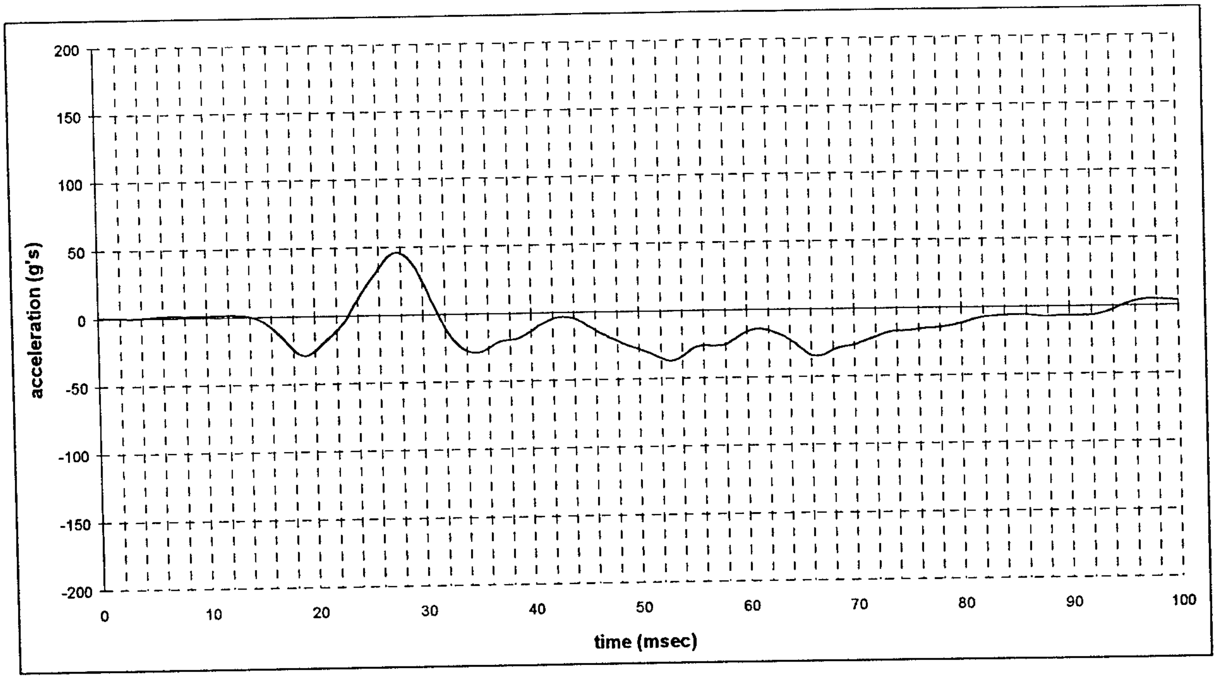


FIGURE A-51. FS 200 RIGHT WSU SEAT PAN VERTICAL ACCELERATION

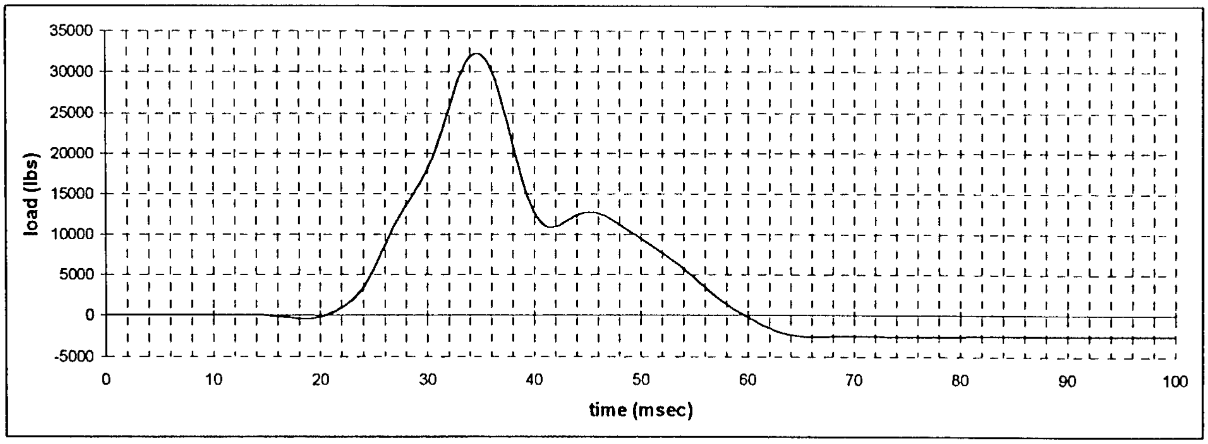


FIGURE A-52. PLATFORM FORWARD FIRST ROW LEFT LOAD

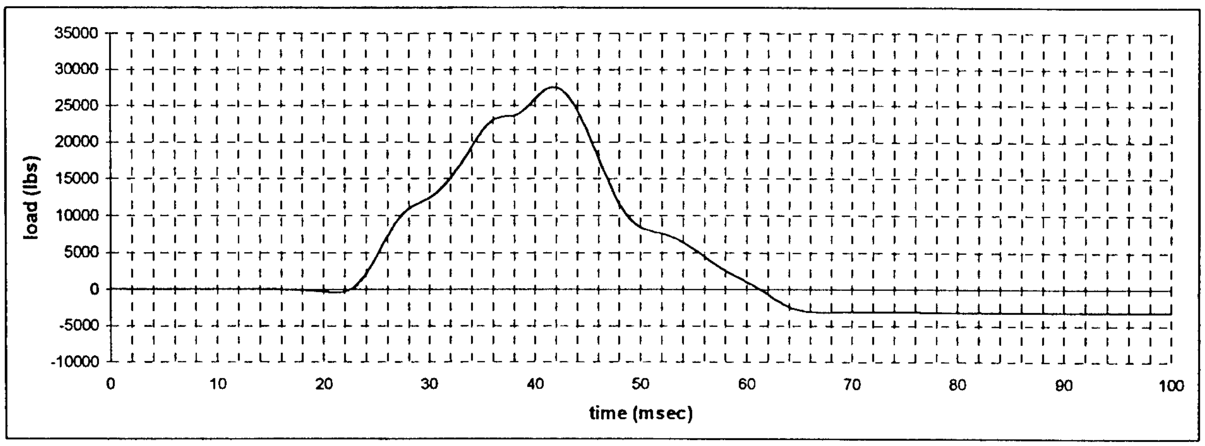


FIGURE A-53. PLATFORM FORWARD FIRST ROW CENTER LOAD

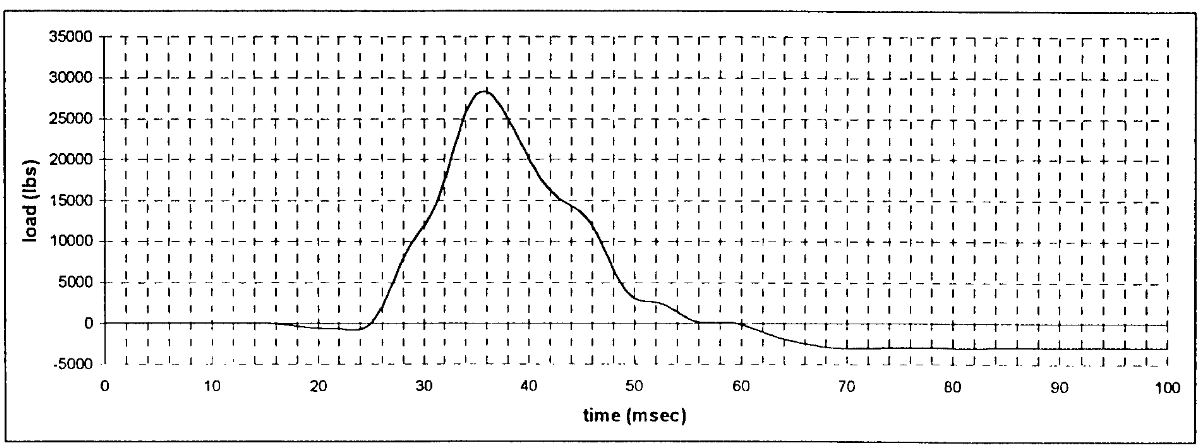


FIGURE A-54. PLATFORM FORWARD FIRST ROW RIGHT LOAD

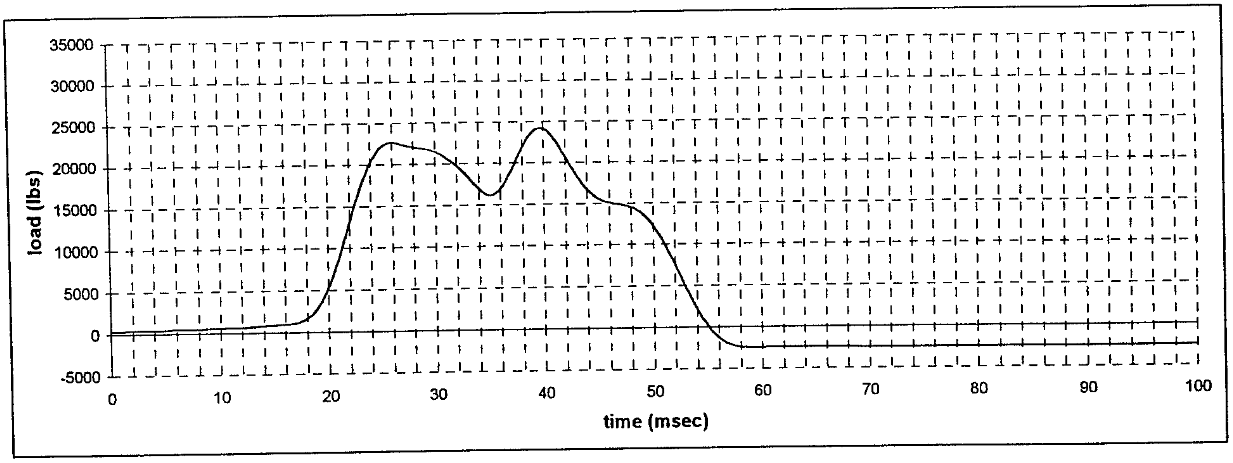


FIGURE A-55. PLATFORM FORWARD SECOND ROW LEFT LOAD

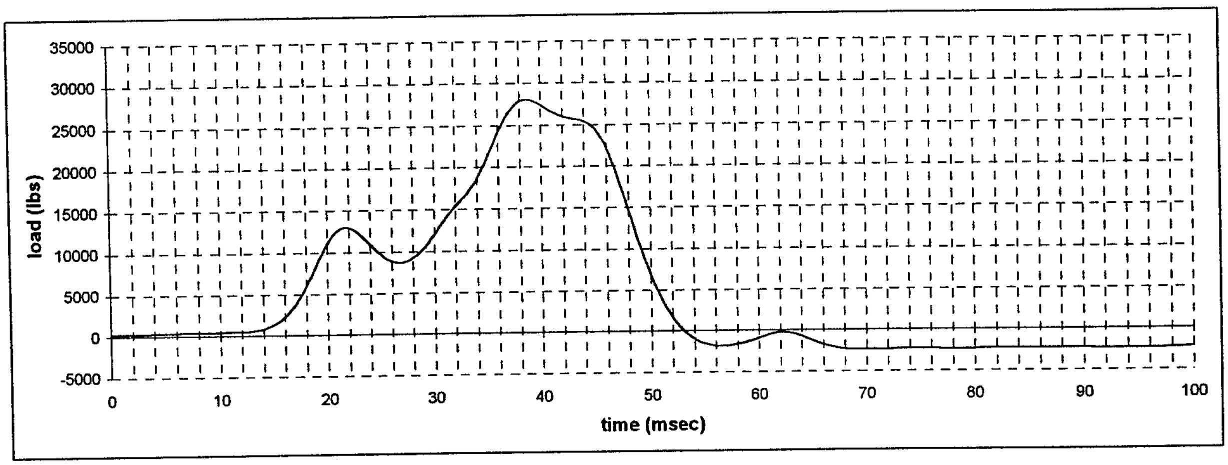


FIGURE A-56. PLATFORM FORWARD SECOND ROW CENTER LOAD

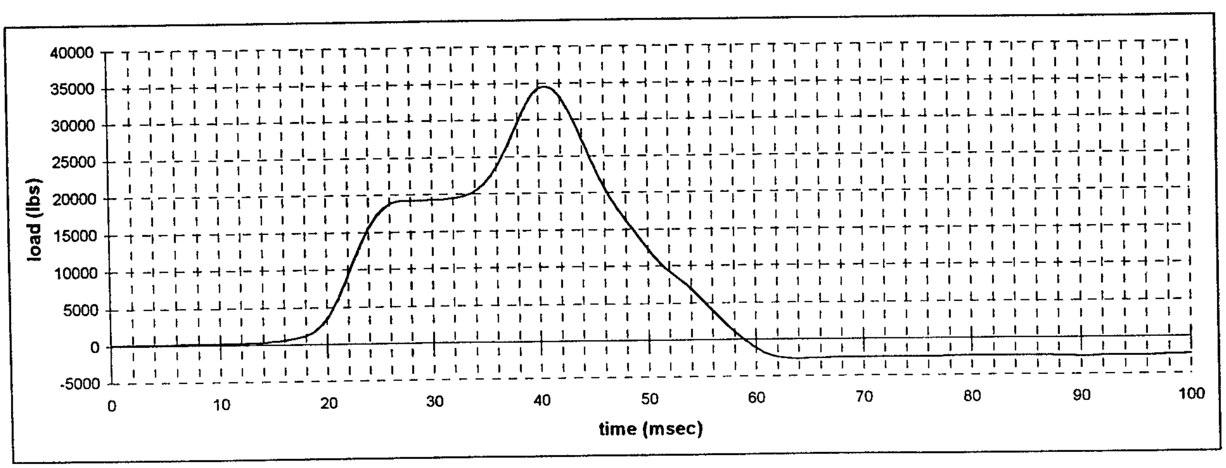


FIGURE A-57. PLATFORM FORWARD SECOND ROW RIGHT LOAD

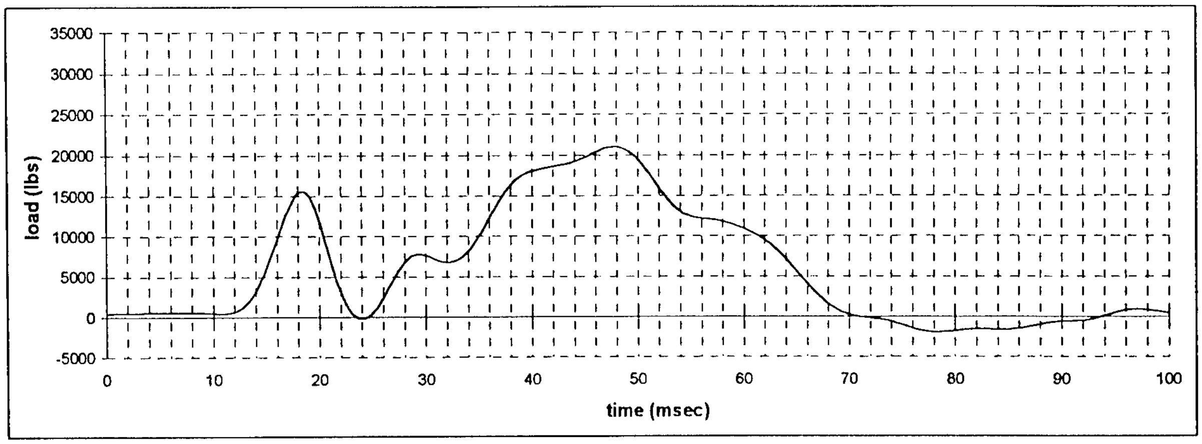


FIGURE A-58. PLATFORM FORWARD THIRD ROW LEFT LOAD

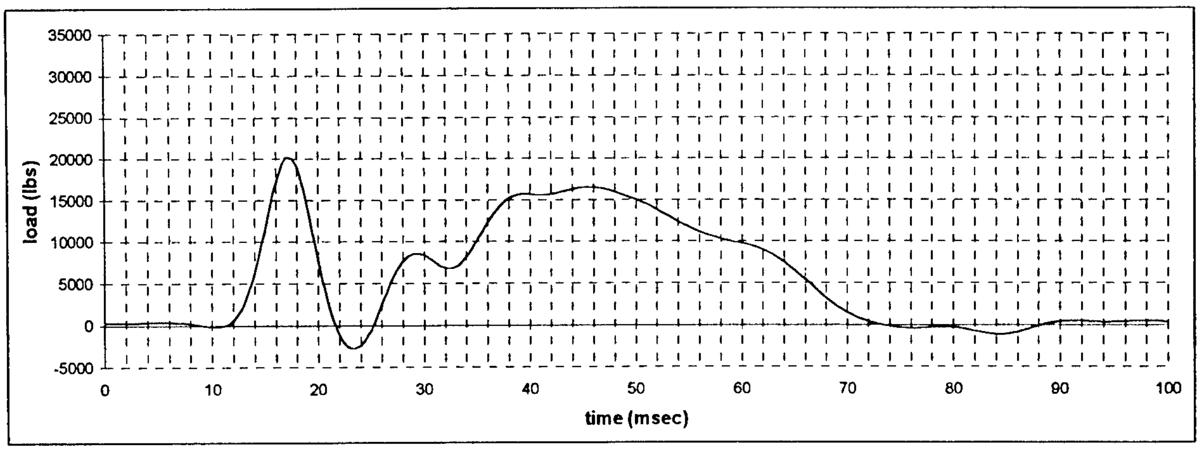


FIGURE A-59. PLATFORM FORWARD THIRD ROW CENTER LOAD

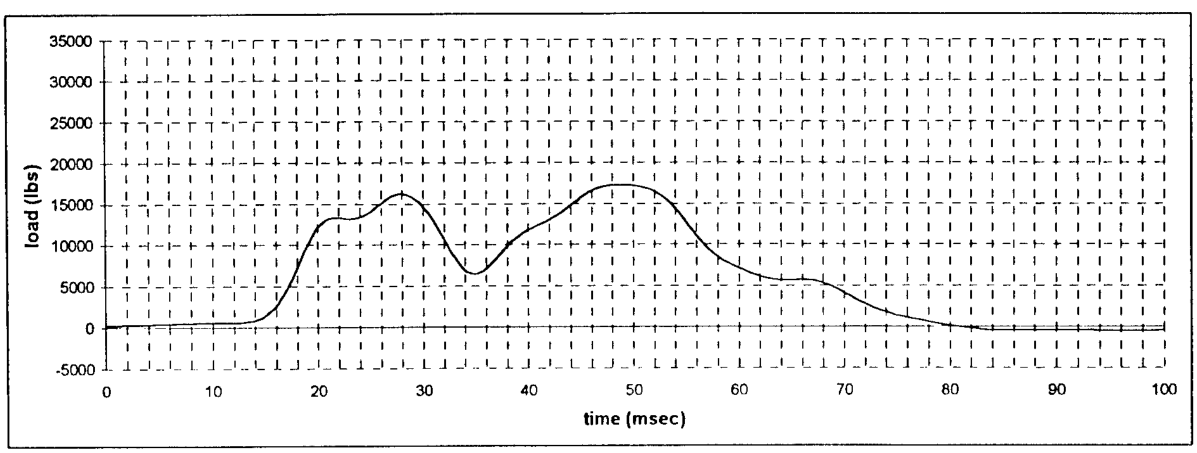


FIGURE A-60. PLATFORM FORWARD THIRD ROW RIGHT LOAD

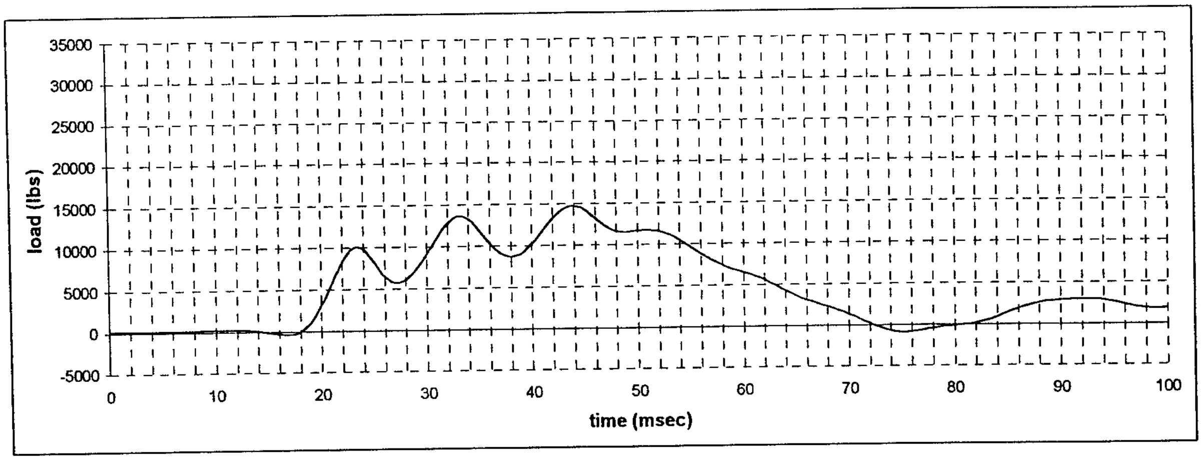


FIGURE A-61. PLATFORM FORWARD FOURTH ROW LEFT LOAD

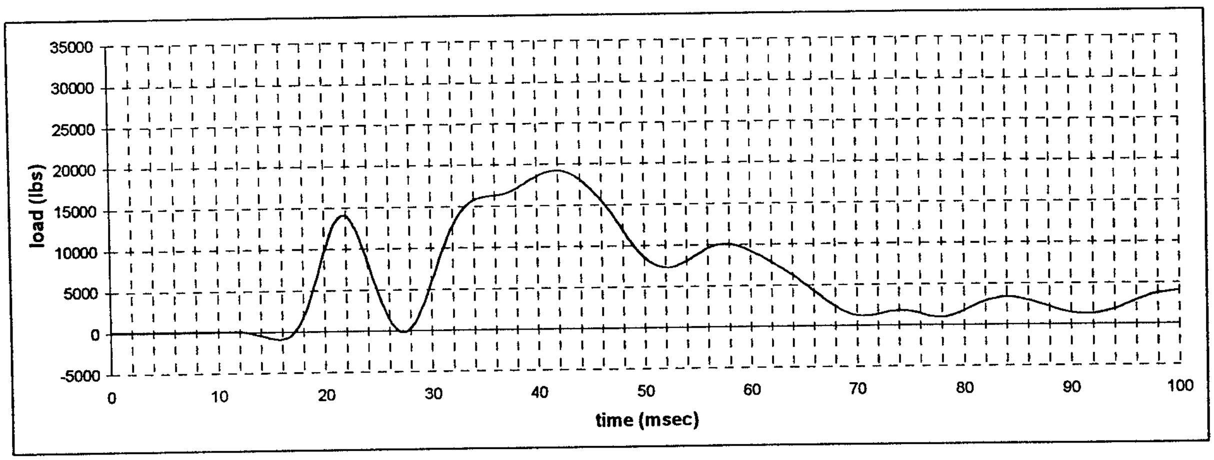


FIGURE A-62. PLATFORM FORWARD FOURTH ROW CENTER LOAD

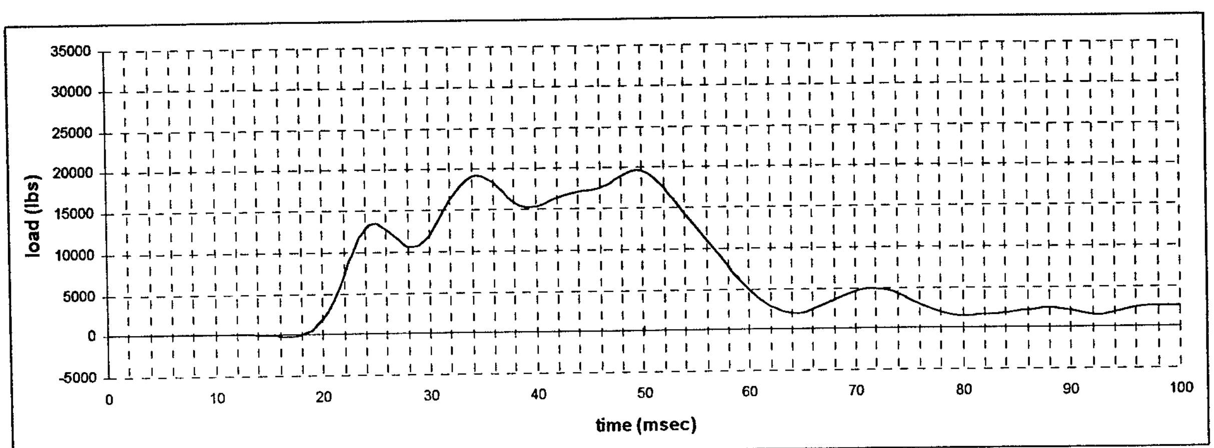


FIGURE A-63. PLATFORM FORWARD FOURTH ROW RIGHT LOAD

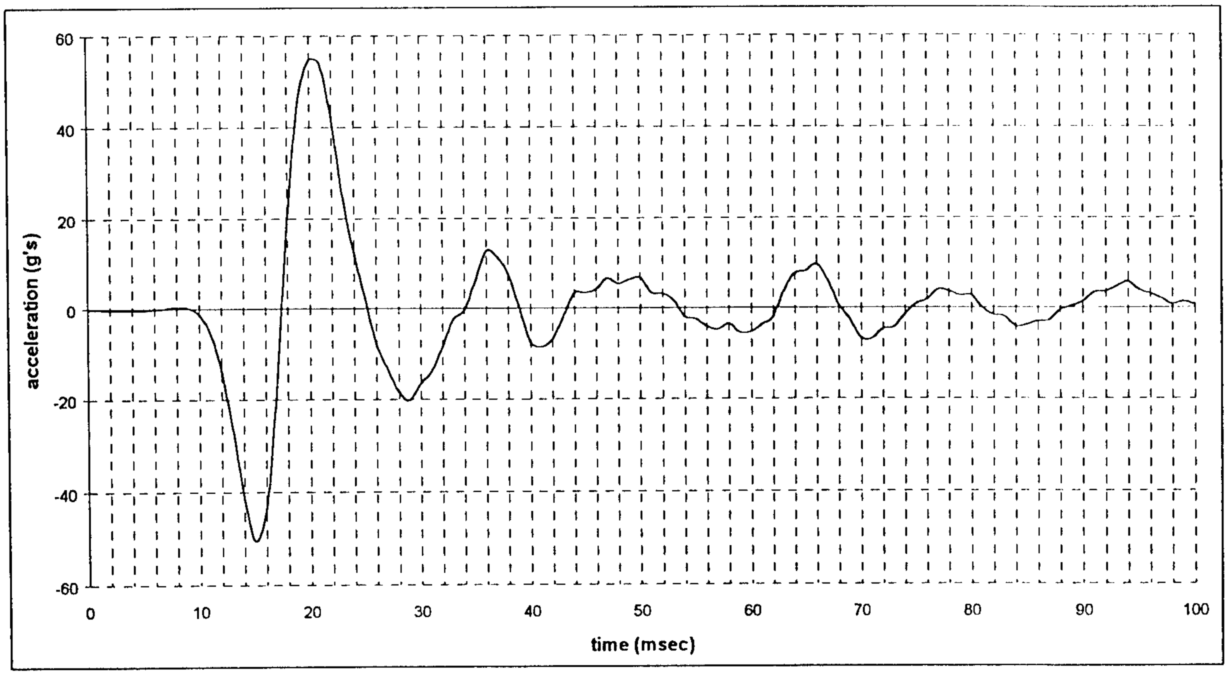


FIGURE A-64. PLATFORM VERTICAL ACCELERATION (750 g RANGE SENSOR)

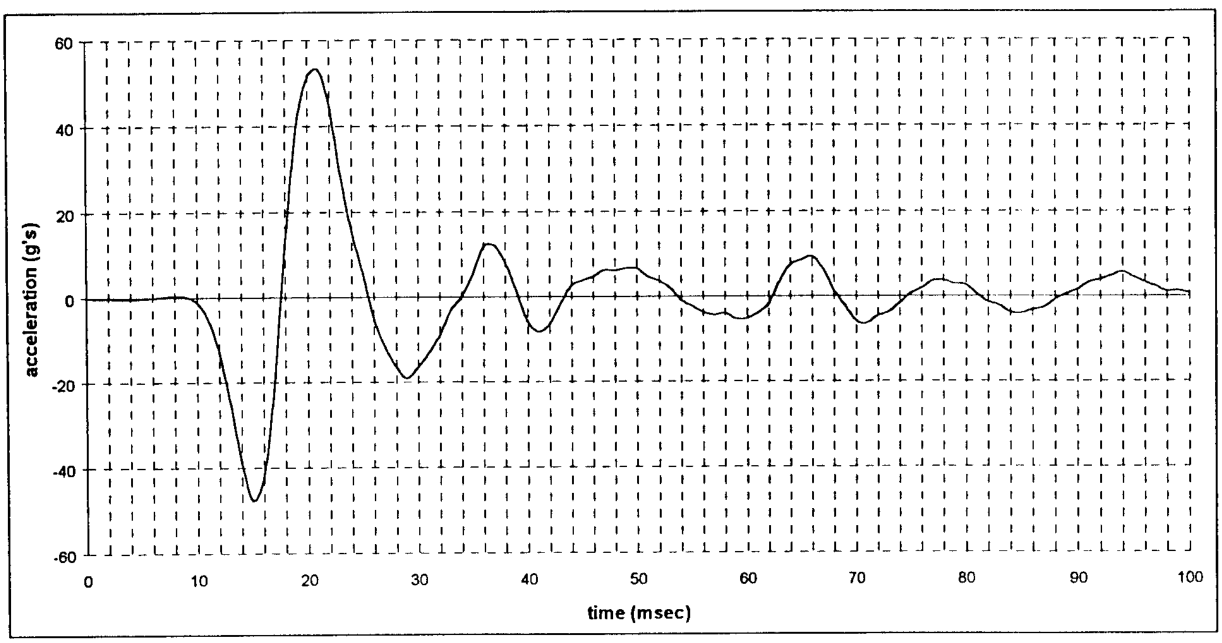


FIGURE A-65. PLATFORM VERTICAL ACCELERATION (100 g RANGE SENSOR)

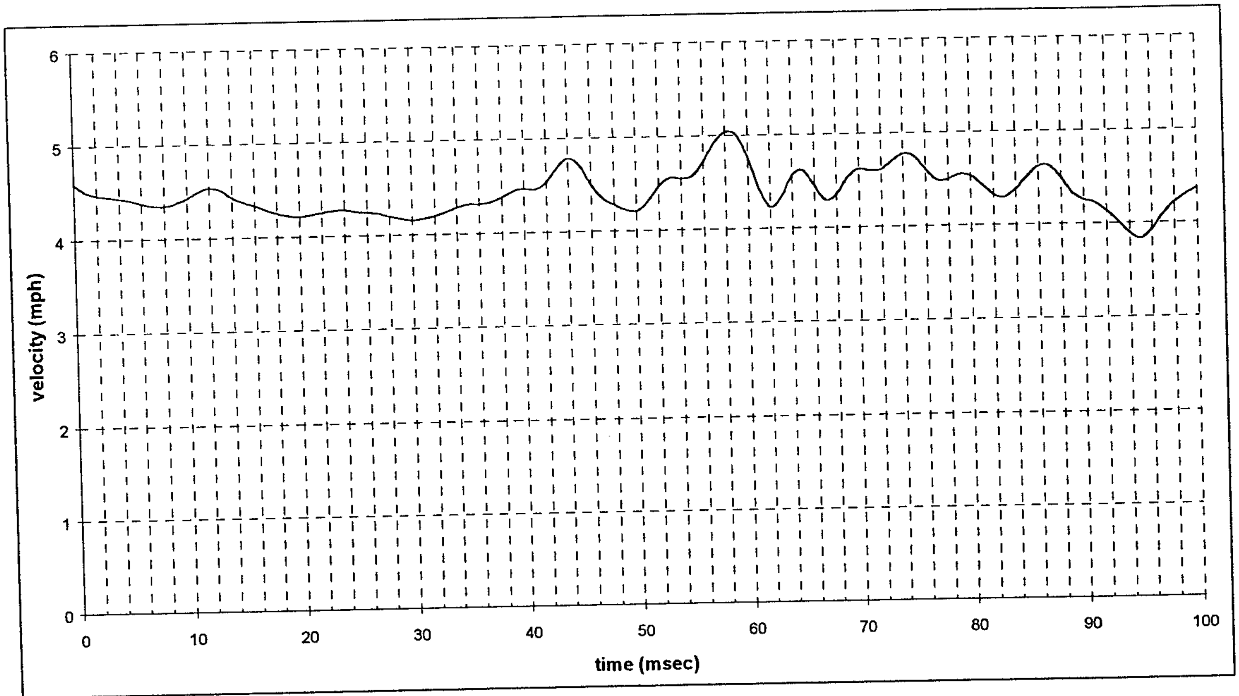


FIGURE A-66. WIND VELOCITY

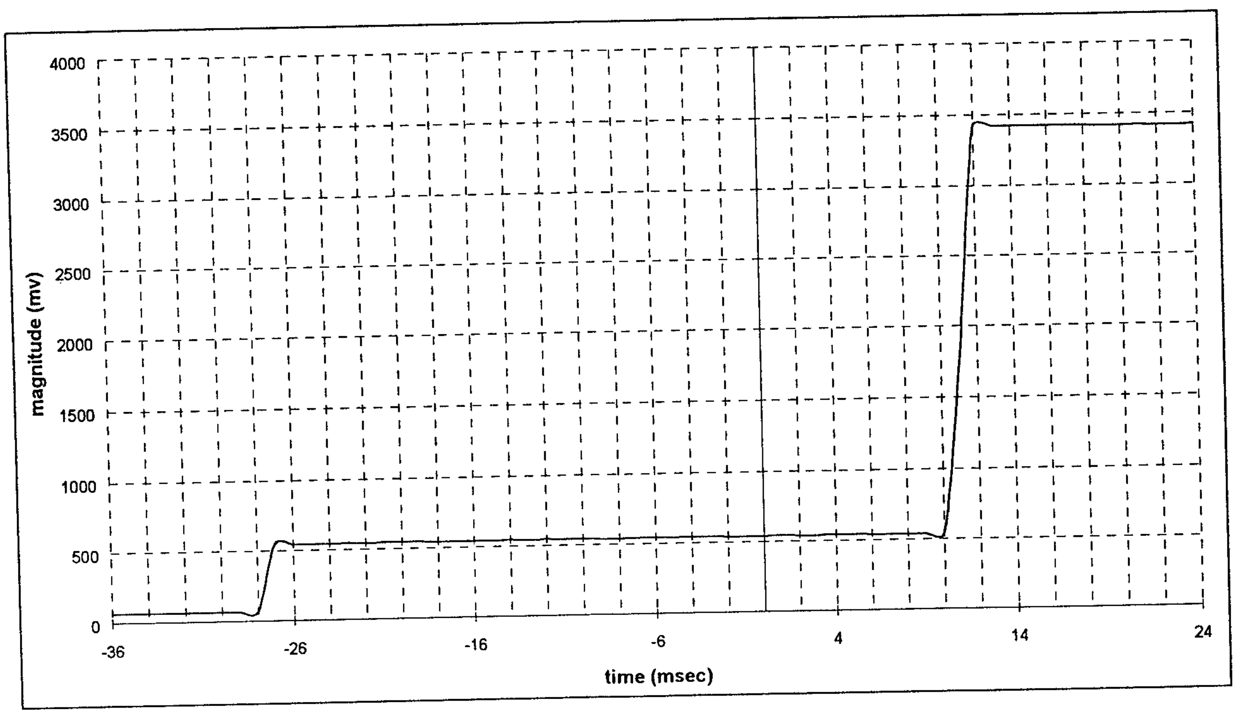


FIGURE A-67. MEASURED TIME DURING 1 FOOT DISTANCE PRIOR TO IMPACT

APPENDIX B—TYPICAL RAW TEST DATA

NO CLIPPING DATA (FIGURE B-1, FIGURE B-2)

MINOR CLIPPING DATA (FIGURE B-3, FIGURE B-4)

MAJOR CLIPPING DATA (FIGURE B-5, FIGURE B-6)

NO CLIPPING DATA

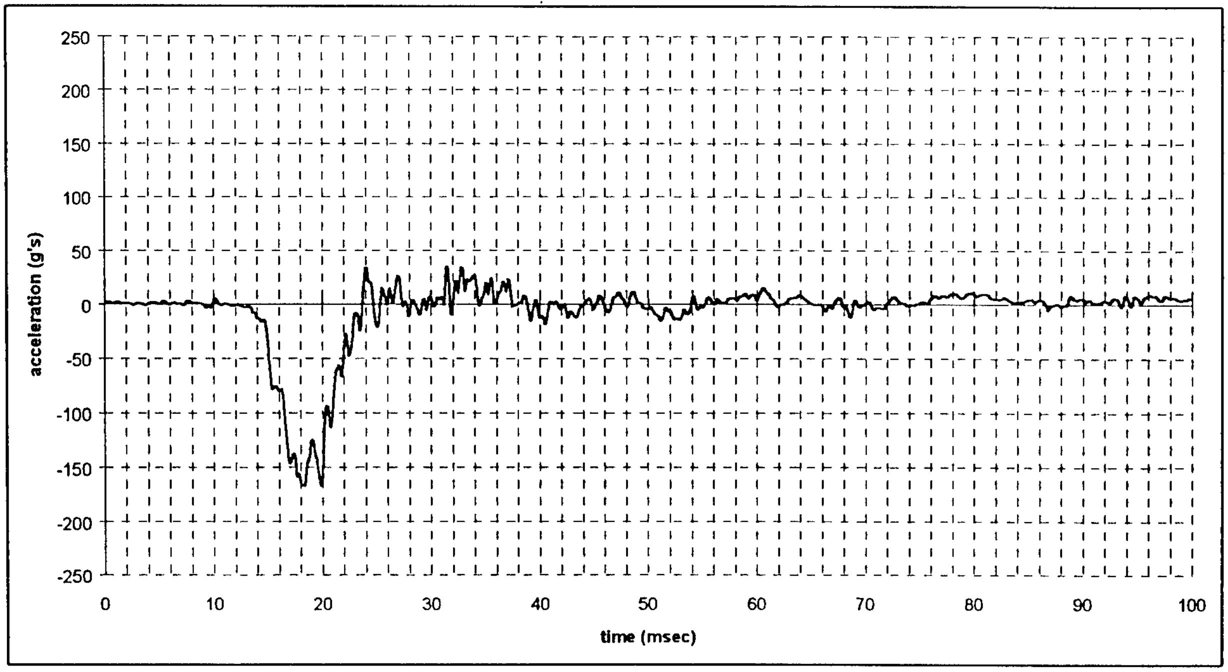


FIGURE B-1. FS 200 LEFT WALL VERTICAL ACCELERATION (750 g RANGE SENSOR)

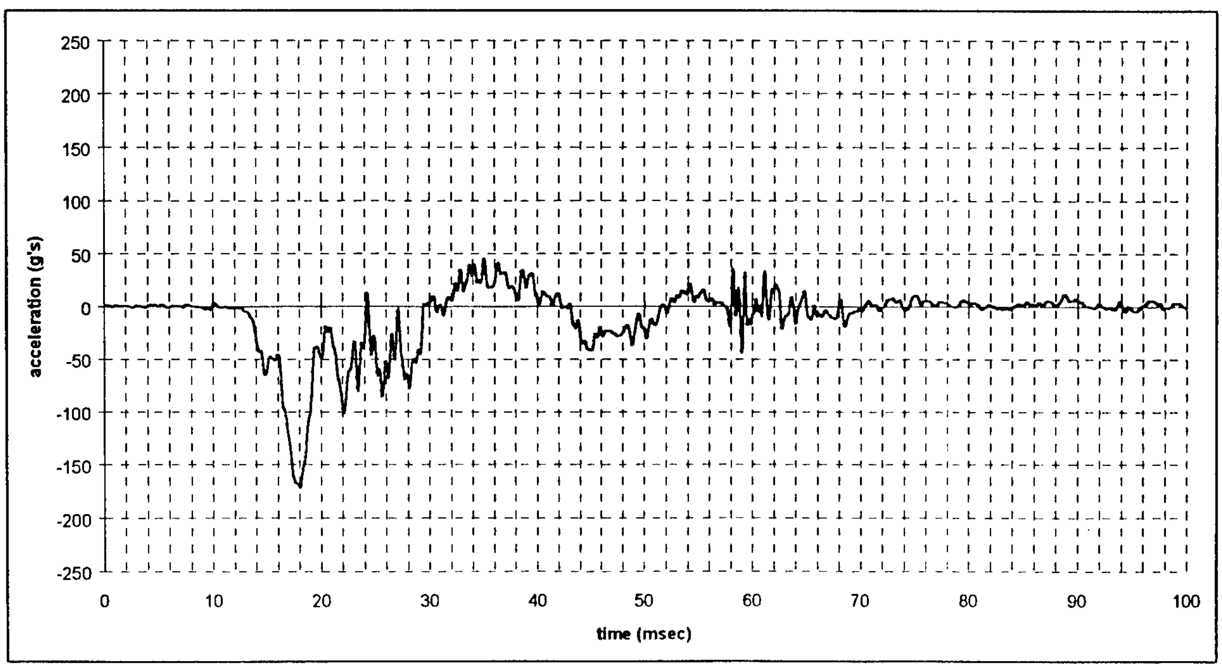


FIGURE B-2. FS 260 RIGHT WALL VERTICAL ACCELERATION

MINOR CLIPPING DATA

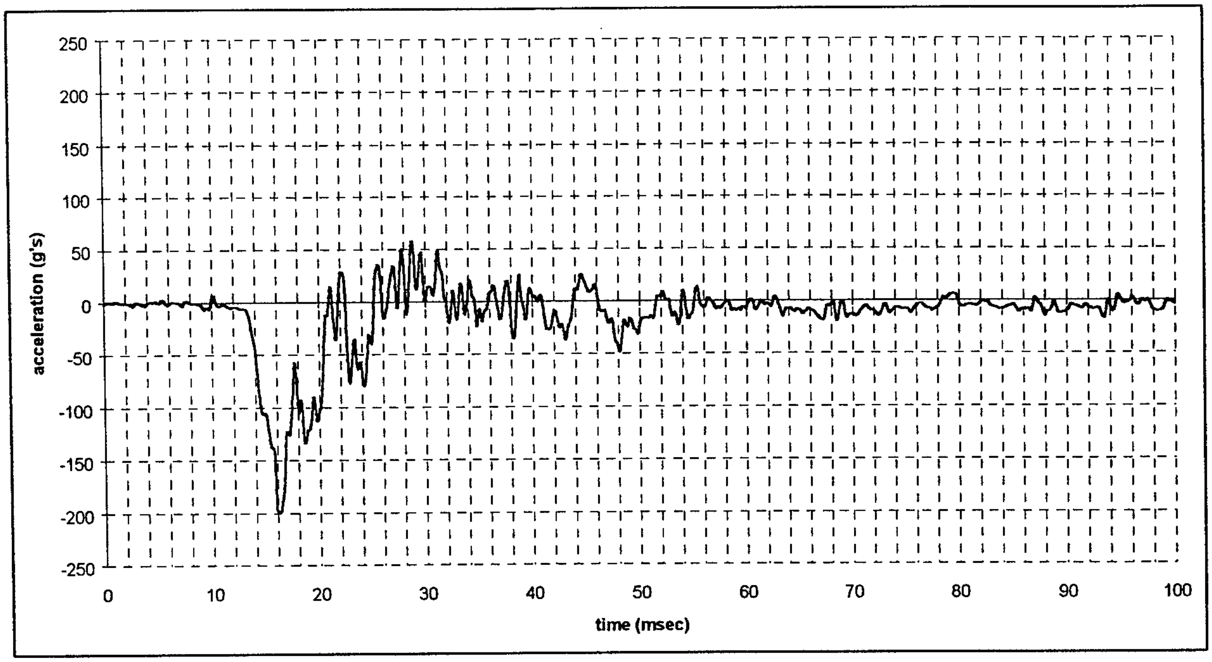


FIGURE B-3. FS 260 LEFT WALL VERTICAL ACCELERATION

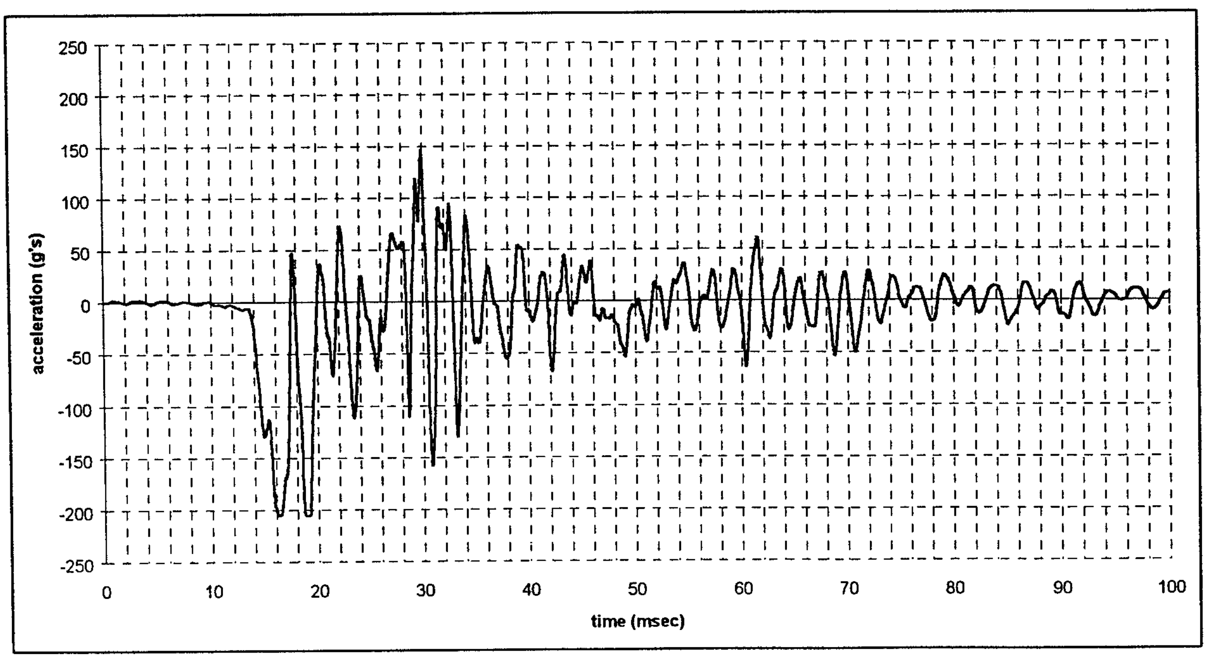


FIGURE B-4. FS 260 LEFT WALL SEAT TRACK VERTICAL ACCELERATION

MAJOR CLIPPING DATA

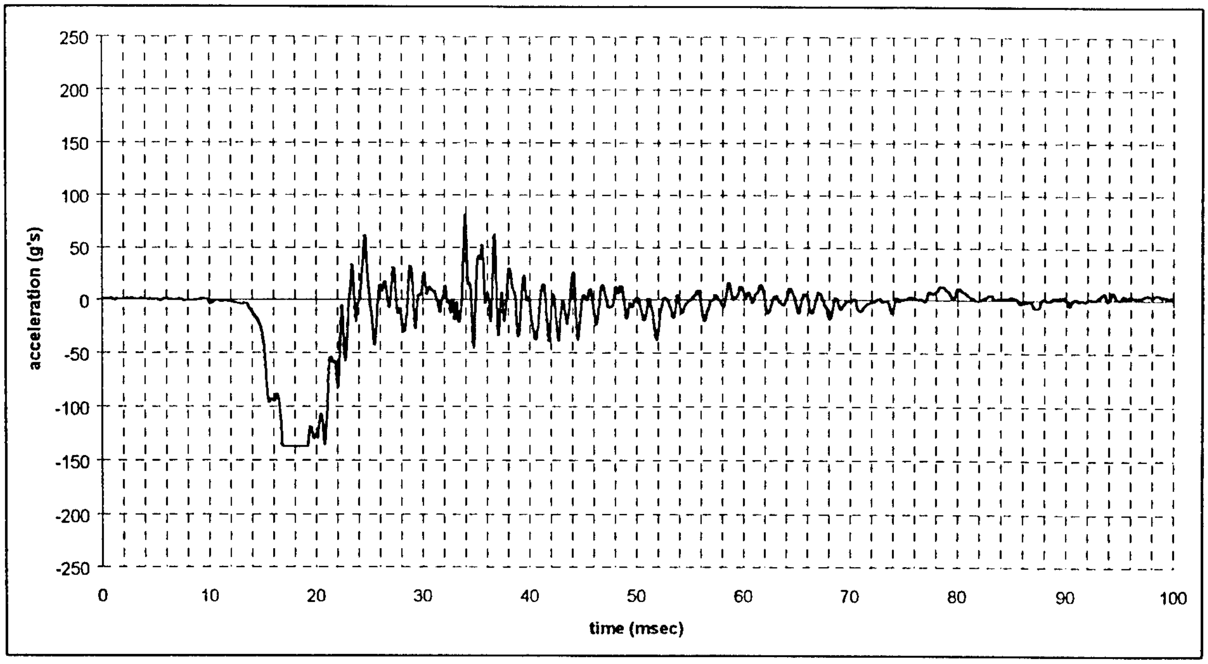


FIGURE B-5. FS 200 LEFT WALL VERTICAL ACCELERATION (100 g RANGE SENSOR)

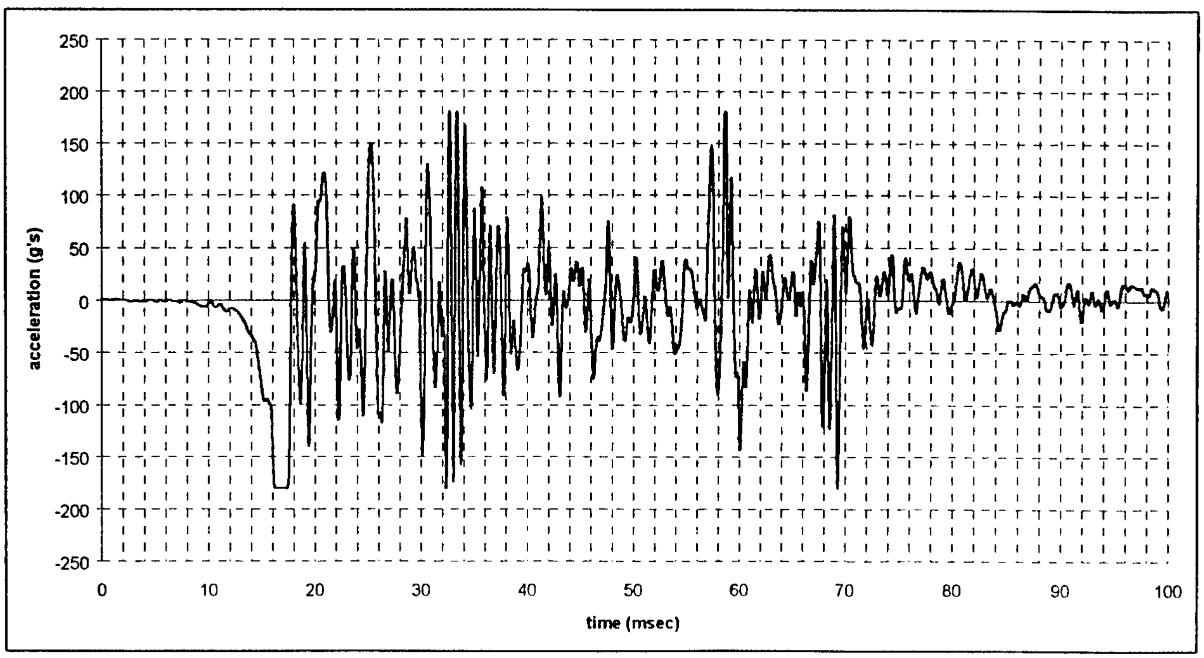


FIGURE B-6. FS 260 FLOOR SEAT TRACK LEFT VERTICAL ACCELERATION